NIAGARA MOHAWK POWER CORPORATION
OSWEGO UNIT 5

316(a) DEMONSTRATION SUBMISSION

NPDES PERMIT #070 0X2 2 000632
NY (0003212)

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LIST OF ABBREVIATIONS

Organizations and Acts

EPA	Environmental Protection Agency
FWPCA	Federal Water Pollution Control Act
LMS	Lawler, Matusky & Skelly Engineers
LOTEL	Lake Ontario Environmental Laboratory
NMPC	Niagara Mohawk Power Corporation
NPDES	National Pollutant Discharge Elimination System
PASNY	Power Authority of the State of New York
QLM	Quirk, Lawler & Matusky Engineers

Dimensions

cfs	cubic feet per second
ft, ft^2	feet, foot; square feet
fps, ft/sec	feet per second
gal	gallon(s)
mgd	million gallons per day
mi	mile(s)
mph	miles per hour
m	meter(s)
mm	millimeter(s)
cm/sec	centimeters per second
cm^2	square centimeter(s)
m^3/sec	cubic meters per second
km	kilometer(s)
g	gram(s)
mg/l	milligrams per liter
psi	pounds per square inch

Chemicals

SiO_2	Silicon dioxide
PO_4	Phosphate
Cl	Chlorine
NaOH	Sodium hydroxide
Na_2HPO_4	Disodium phosphate
DO	Dissolved oxygen
BOD	Biological oxygen demand
^{14}C	Radioactively labeled carbon

Other Abbreviations:

BTU	British Thermal Unit
KWHR	Kilowatt hour
MWe	megawatts electric
MWT	megawatts thermal
CTM	critical thermal maximum
ΔT	delta (change in) temperature
ppm	parts per million
mmhos	millimhos
atm	atmosphere(s)
c/f	catch per effort
yr	year(s)
$MA7CD_{10}$	minimum average seven-consecutive-day flow having a once in ten year frequency
WS I	Water body segment I
WS II	Water body segment II
OSWW, OSWP	Oswego sampling station designations
sp.,spp.	species
#,no	number
dynes/cm	dynes per centimeter
hr, hrs	hour, hours
wt.	weight
EL	elevation
µ	micro, micron

SUMMARY OF FINDINGS

1. Oswego Steam Station Unit 5 has just begun operating at its full load potential. Therefore, the thermal discharge effects on the biota must be predicted, as prescribed in the technical guidance manual. The predictions show that operation of the discharge will assure the protection and propagation of the representative important species. Although the Oswego Unit 5 discharge is technically a "new source" requiring a Type II demonstration, aquatic studies have been conducted at the site since 1970 and information from these studies and studies conducted at an adjacent site are incorporated in this submission.

2. The Oswego Unit 5 generating station is operating at loads up to 75% of its 850 MWe maximum capacity. The projected seasonal loads for the year of highest loading are summarized below:

Season	Percentage Max. Load	Unit Output MWe	Heat Discharge (Billion BTU/Hr)	Condenser ΔT (°F)	Discharge ΔT (°F)
Summer	53.4	453.9	2.244	18.3	16.4
Fall	70.2	596.7	2.765	22.5	20.0
Winter	48.7	414.9	2.052	17.4	15.7
Spring	30.0	255	1.443	11.8	10.8

These seasonal loads will result in reduced impact as compared with the impacts predicted for capacity operation.

3. The receiving water body (Lake Ontario) is a temperate lake with winter surface temperatures approaching 0°C (32°F) near the site and summer temperatures in excess of 23°C (74°F). The lake as a whole develops stratification in summer but the stratification near the discharge is transient in response to large scale winds and currents. The frequencies of currents alongshore determined from data collected in the Oswego vicinity leads to a natural selection of the two adjacent water body segments shown in Figure S-1. These segments are used as receiving water body segments for quantitative impact descriptions.

The existing thermal discharges near the Oswego Unit 5 discharge include the Nine Mile Point Unit 1 AND the James A. FitzPatrick discharges. The Oswego Units 1-4 discharge to the turning basin at the Oswego Harbor.

4. The thermal discharge from Oswego Unit 5 enters the lake via a high velocity submerged diffuser located in 7.9 m (26 ft) water depth off the Oswego generating station. The effluent is diluted 6.2:1 before

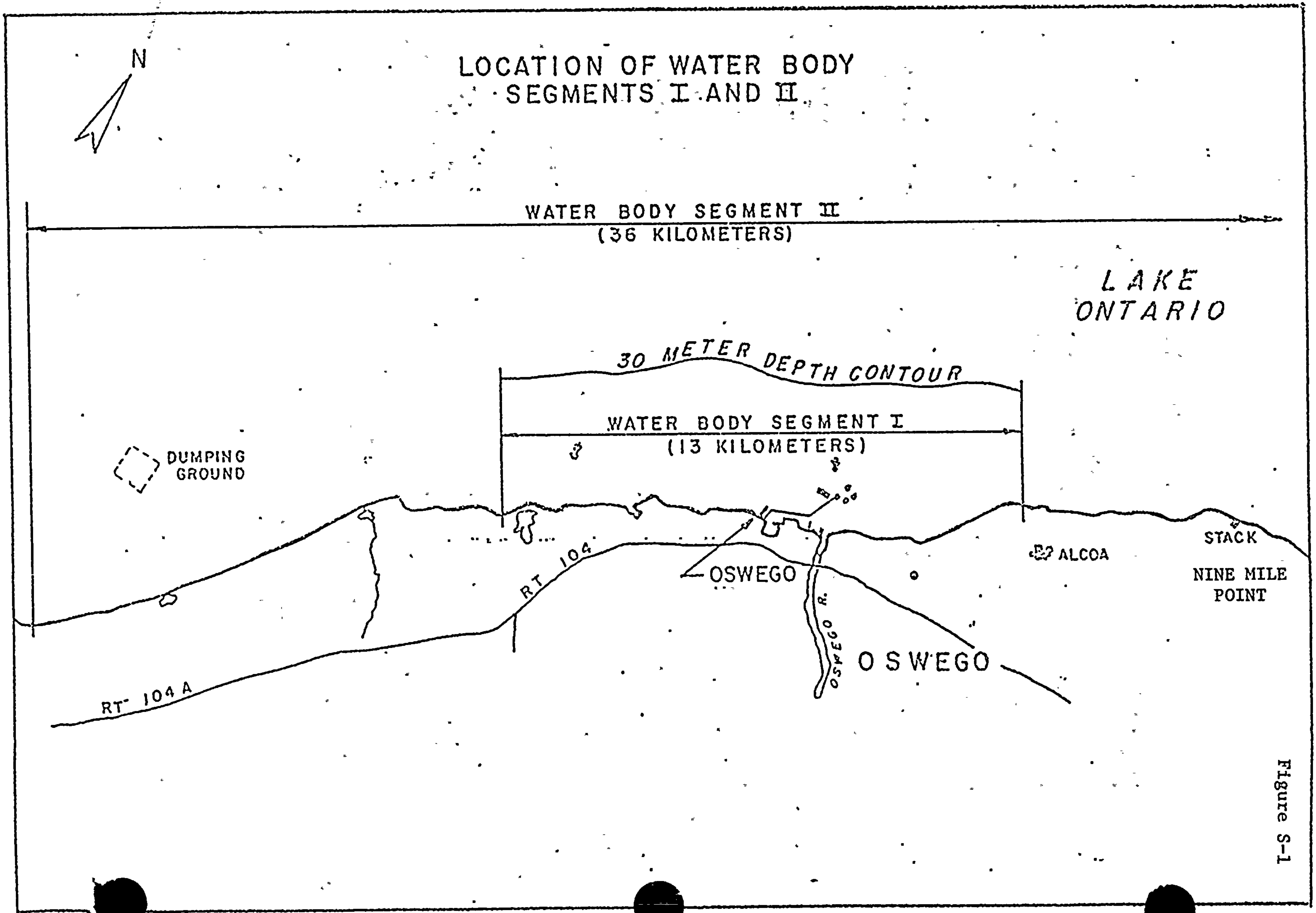

N
LOCATION OF WATER BODY
SEGMENTS I AND II
WATER BODY SEGMENT II
(36 KILOMETERS)
LAKE
ONTARIO
30 METER DEPTH CONTOUR
WATER BODY SEGMENT I
(13 KILOMETERS)
DUMPING
GROUND
STACK
ALCOA
NINE MILE
POINT
OSWEGO
RT 104
OSWEGO R.
OSWEGO
RT 104 A

Figure S-1

the buoyant plume reaches the waters surface. The maximum surface temperature elevation is predicted to be only 2.5°C (4.6°F) and the discharge will be in compliance with New York State Water Quality Standards and thermal criteria. The plume volume, areas and entrainment rates are utilized in subsequent sections for impact assessment.

5. Baseline studies have been conducted in the Nine Mile Point - Oswego area since 1963. The studies at Oswego in 1970 through 1974 describe the communities present at the site. There are no ecological features of the area which are unique relative to Lake Ontario as a whole.

6. The representative important species selected by the EPA include Gammarus sp., alewife, coho salmon, brown trout, rainbow smelt, threespine stickleback, smallmouth bass, and yellow perch. Life history information for these species and for spottail shiner and white perch are presented with a summary of available thermal data to be used in assessing the predicted plume impact.

7. Potential impacts of the discharge include thermal stress imposed by exceeding a species' lethal threshold, shut down effects of cold shock, plume entrainment of organisms into potentially lethal areas of the plume, effects of hydrostatic pressure redirection in the plume as it rises to the surface, shear forces in the plume, and oxygen depletion resulting from heat addition or biological oxygen demand.

It is shown in the demonstration that the above delineated factors do not always result in 100% mortality of the aquatic organisms. For the purposes of this demonstration, however, it is conservatively assumed that all organisms that are entrained or enter into thermally lethal portions of the plume will suffer 100% mortality regardless of their exposure time or other mitigating factors. Since the warmest portion of the plume includes those portions where maximum shear and pressure change occur, the mortality assumptions for thermally lethal isotherms include the possible effects of pressure and shear as well.

8. The designated plant load factors, water body segments, plume description, representative species and significant isotherms are used to define representative impact matrices. The matrix elements computed are listed in Table S-1 and include:

(1) The volumes of the water body segments occupied by the seasonal average Unit 5 plume temperature rises of 2° and 3°C (3.6° and 5.4°F) which may exclude viable fish residency.

(2) The entrainment of passive organisms such as larvae and Gammarus with flow into the same isotherms for the Unit 5 plume.

(3) The entrainment flow into all thermal plumes in the adjacent water body segments.

(4) The species-specific entrainment flow for critical months into lethal threshold isotherms for the representative important fish species.

9. As shown in Table S-1 and documented in the submission, the portion of the water body segments occupied by the plume resulting from Oswego Unit 5 and assumed to be unsuitable for habitation by certain fish species is not significant. Specifically, the 2°C (3.6°F) ΔT isotherm encloses 3/100,000ths of the volume of the smaller water body segment. This is comparable to a drop of water in a fifteen gallon tank. In addition, the benthic area that is exposed to heated water is insignificant.

As shown in the Table S-1, the conservatively estimated cropping[1] due to Oswego Unit 5 alone and the cumulative impact of Oswego Unit 5, Nine Mile Point Unit 1 and the FitzPatrick plant is insignificant within the water body segments studied and the lake as a whole.

10. This demonstration generally follows the procedures outlined in the 316a Technical Guidance Manual and includes several quantitative features not described in the manual. It provides a clear basis for a decision by the EPA regarding the proposed alternative effluent limitations. Specifically, the minimal impacts predicted to result from the operation of the thermal outfall as built and currently operated assures the protection and propagation of representative important species and hence the protection and propagation of the balanced indigenous community in and on the receiving water body, Lake Ontario.

(1) Cropping is the percentage of potential impact of the station on an aquatic community based on a knowledge of station effects and lake populations (see Chapter VIII).

TABLE S-1

SUMMARY OF IMPACTS

Season	Load (%)	TEMPERATURE ELEVATION (°C)	VOLUME OF SEGMENT AFFECTED (%)	CROPPING BY ENTRAINED FLOW BY UNIT 5 FROM SEGMENT I (%)	CROPPING BY ENTRAINED FLOW BY ALL STATIONS FROM SEGMENT II (%)
	Capacity	2	.00341	2.94	1.95
		3	.00039	0.32	0.22
Summer	53.4	2	.00037	0.31	0.33
		3	.00031	0.27	0.28
Fall	70.2	2	.00039	0.33	0.29
		3	.00034	0.29	0.26
Winter	48.7	2	.00037	0.31	0.35
		3	.00031	0.27	0.30
Spring	30.0	2	.00031	0.27	0.41
		3	.00024	0.20	0.31

THERMAL CROPPING IN WATER BODY SEGMENT I

Species	Highest Rate % Month	Rate	Annual % (1)
Alewife	August	0.30	0.05
Brown trout	August	0.21	0.02
Coho Salmon	August	0.21	0.04
Rainbow smelt	insufficient data		insufficient data
Smallmouth bass		0	0
Spottail shiner		0	0
Threespine stickleback	Summer	0.09	0.09
White perch	Nov-Dec	0.18	0.04
Yellow perch	August	0.05	0

(1) Or appropriate subsample described in text.

I. INTRODUCTION

A. BACKGROUND

On May 22, 1974, the staff for Region II of the U. S. Environmental Protection Agency EPA issued a draft National Pollutant Discharge Elimination System (NPDES) permit for the Oswego Steam Station Unit 5 in accordance with the provisions of the Federal Water Pollution Control Act (FWPCA). On June 28, 1974, Niagara Mohawk Power Corporation (NMPC) requested pursuant to Section 316(a) of the FWPCA, that the regional Administrator impose alternative thermal effluent limitations to those described in the draft permit. On August 2, 1974, Niagara Mohawk provided documentary evidence in support of its request. On February 24, 1975, NMPC was issued the final NPDES Permit for Oswego Unit 5. The final permit did not include the requested alternative thermal effluent limitations.

In the memorandum transmitted with the final permit, and in discussions with NMPC, the technical staff of Region II indicated that the information submitted in support of the request for alternative thermal effluent limitations was insufficient. In response, Niagara Mohawk has prepared this document supplementing its original Section 316(a) submittal in the areas identified by the Region II staff. Niagara Mohawk believes that its original conclusions are verified and reinforced by this supplemental submittal. On June 30, 1975, NMPC submitted to the EPA its recommendations for the selection of Representative Important Species at Oswego. On August 11, 1975, the Regional Administrator forwarded a copy of the designated list of Representative Important Species for the Oswego locality of Lake Ontario (see Table I-1).

This document provides additional information aligned with a 316(a) Type II demonstration. The content of this document generally follows the procedures presented in the draft document entitled "316(a) Technical Guidance-Thermal Discharges" published September 30, 1974, by the Water Planning Division of the Environmental Protection Agency and the guidance provided by the Region II staff during the technical meetings. The information contained herein includes previously submitted data.

B. DEMONSTRATION APPROACH AND RATIONALE

Oswego Steam Station Unit 5 has just begun operating at its full load potential. Therefore, the thermal discharge effects on the aquatic biota have been predicted, by showing that the discharge will assure the protection and propagation of a balanced indigenous population.

TABLE I-1

LIST OF REPRESENTATIVE SPECIES FOR LAKE ONTARIO
(Oswego 5, Oswego 6, Nine Mile Point 1, FitzPatrick)

Macroalgae
*Cladophora - habitat former

Macroinvertebrates
Gammarus sp. - lower trophic level food source

Fish

Clupeidae
Alewife - forage, community dominant

Salmonidae
Coho salmon
Brown trout - major predator species, thermally sensitive

Osmeridae
Rainbow smelt - forage

Gasterosteidae
Threespine stickleback - forage

Centrarchidae
Smallmouth bass - sport species

Percidae
Yellow perch - sport species, thermally sensitive

* Nine Mile Point Only.

The rationale for this demonstration follows the "representative important species" approach suggested in the guidance manual. Impacts on these representative species are quantified through computation of matrices including thermal sensitivities of the representative species, months of the year, thermal exclusion zones, and entrainment into the thermal plume.

Although the Oswego Unit 5 discharge is technically a "new source" requiring a Type II demonstration, aquatic studies have been conducted at the site since 1970. Additional studies have been conducted at an adjacent site, Nine Mile Point, since 1963.

The information available from these studies will assist in confirming predicted effects. Therefore, extensive reference to studies at the Nine Mile and Oswego 1-4 locations submitted under separate cover to the EPA are utilized throughout this document.

C. FORMAT OF THE DOCUMENTATION

In the development of this document, Niagara Mohawk has taken a logical step-by-step approach to the demonstration methodology.

Chapter II through IV provide the basis for the impact assessment presented in the submission. Chapter II presents a detailed description of Oswego Unit 5 and the associated discharge. Included in this chapter is the predicted frequency by season for representative thermal discharge levels and the seasonal load variation for 1981, which is the year of maximum usage for Oswego Unit 5.

Chapter III describes the hydrographic characteristics of the near and far field. A description is provided of the temperature structure in the lake and the vicinity of Oswego, the topography and geology of the lake bottom in the vicinity of Oswego the general lake circulation patterns and the local currents at the site. The characteristics of the existing major thermal discharge in the vicinity of Oswego are provided in this chapter. Based on these data and the thermal plume analysis a rationale for determining water body segments is developed. This chapter presents this rationale and describes the characteristics and limits of the water body segments.

Chapter IV describes the analysis of the thermal plume resulting from operation of the Oswego Unit 5 diffuser. Based upon this analysis, plume volumes, cross-sectional dimensions of the plume, and the flow entrained into various isotherms within the plume are calculated and presented. These data provide the basis for establishing the maximum potential impact flows, areas and volumes as functions of temperature use for full capacity operation of Oswego Unit 5. Also provided in this chapter is a discussion of the patterns of the thermal plume for different seasons.

Chapter V summarizes the essential characteristics of the biological community found in the Oswego area. The abundance, species composition, and distribution of the biota prior to power plant operation is delineated through the baseline information gathered in studies and at the Oswego and other plants in Lake Ontario. Major biological groups present are considered, in conjunction with the factors which have been shown to affect these aquatic populations in order to assess the operational effects upon the aquatic ecosystem.

Chapter VI presents a discussion of the representative important species selected by the EPA and transmitted to Niagara Mohawk by letter dated August 11, 1975 and other species considered in the demonstration. The basis for selection of each species is discussed and data on the characteristics of each species are provided.

With the data base presented in the previous chapters, Chapter VII considers the thermal, physical, and chemical impacts on the selected species resulting from the thermal discharge from Oswego Unit 5. A summary of the summer lethal threshold temperatures is presented and the effect of shutdowns, currents, shear forces, pressure changes, and chemical alterations are discussed.

The predicted impacts for Oswego Unit 5 on the aquatic biota within the water body segments is quantified and discussed in Chapter VIII. The basis for the conservative evaluations are presented. Potential thermal exclusion zones within the water column and on the lake bottom are identified and the effects of these are presented. The relative effect of plume entrainment including cumulative effects is presented for the water body segments.

Appendix A presents available temperature data by species for the selected species.

II. STATION DESCRIPTION

A. SITE LOCATION AND DESCRIPTION

Niagara Mohawk Power Corporation (NMPC) has installed a fifth unit at its steam electric generating station in Oswego, New York, on the shore of Lake Ontario. The previous four units at the Oswego Steam Station have a combined maximum capacity of 407 megawatts (MWe). Cooling water for the existing station is withdrawn from Lake Ontario, circulated through the condensers, and then discharged to the western leg, or "turning basin" of Oswego Harbor.

The new unit (Unit 5) is oil-fired, with a maximum capacity of approximately 890 MWe gross output. The cooling water for Unit 5 is withdrawn from Lake Ontario and returned to the lake after circulation through the condenser. The location of the Oswego Steam Station is shown in Figure II-1.

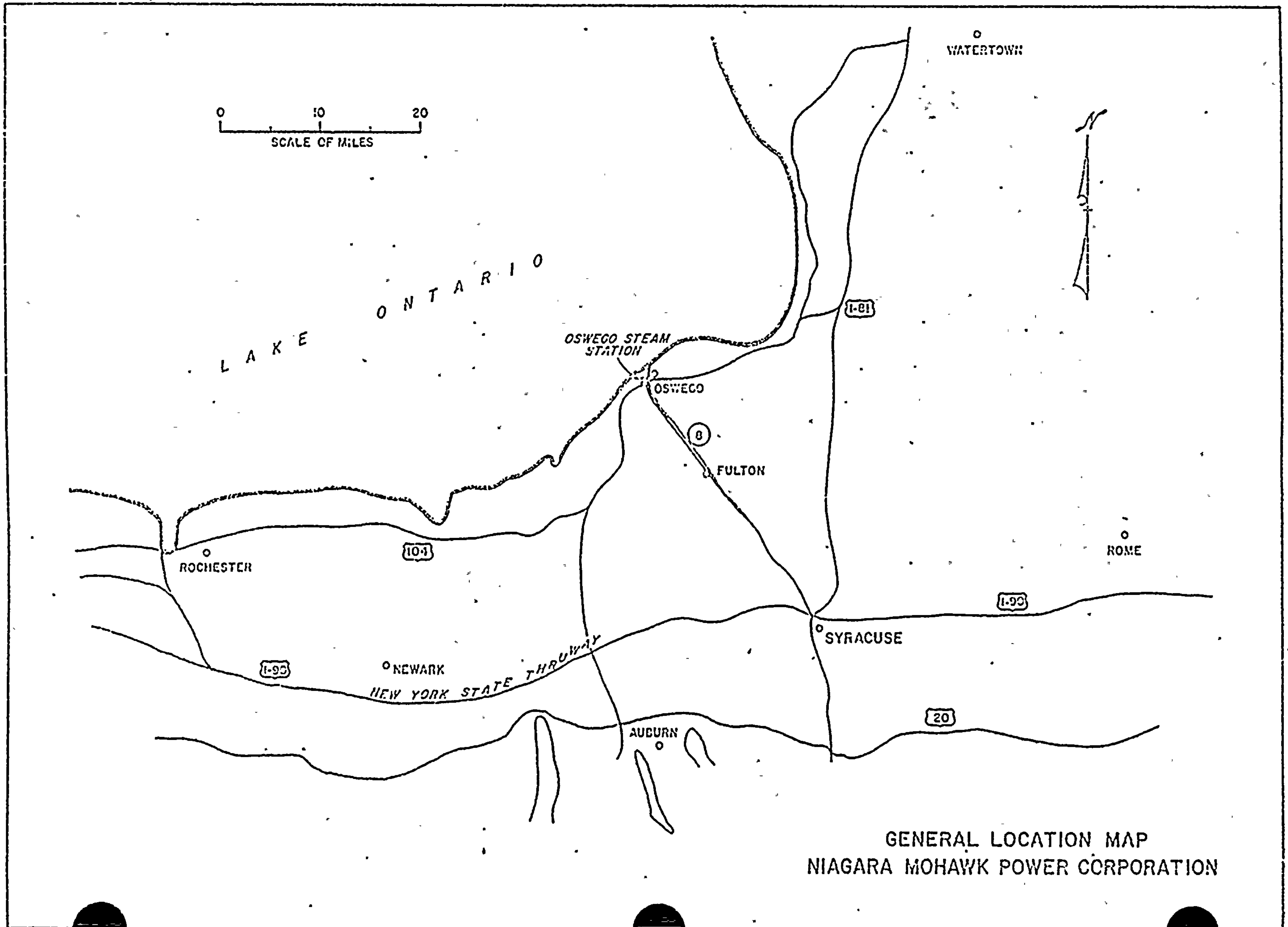
B. DESCRIPTION OF UNIT 5 GENERATING UNIT

The new unit is completely enclosed and contains an oil-fired steam generator designed to produce 6,300,000 pounds of steam per hour at 2,600 pounds per square inch (psi) gauge pressure (normal operation at 2,480 psi gauge), and 1,005°F with a single reheat to 1,005°F (1,005/1,005°F) and a reheat turbine-generator with a guaranteed rating of 816 MWe at 2,400 psi gauge. The station plot plan is shown in Figure II-2.

Steam generated in the boiler leaves the superheater section at 2,480 psi gauge pressure and a final superheat temperature of 1,005°F. The steam passes to the turbine where its heat energy is converted to mechanical energy to drive the turbine shaft. The steam then returns to the steam generator and is reheated to 1,005°F. It again passes to the turbine where additional mechanical energy is imparted to the shaft. The mechanical energy produced in the turbine is transmitted to the generator via a common shaft, and converted into electrical energy.

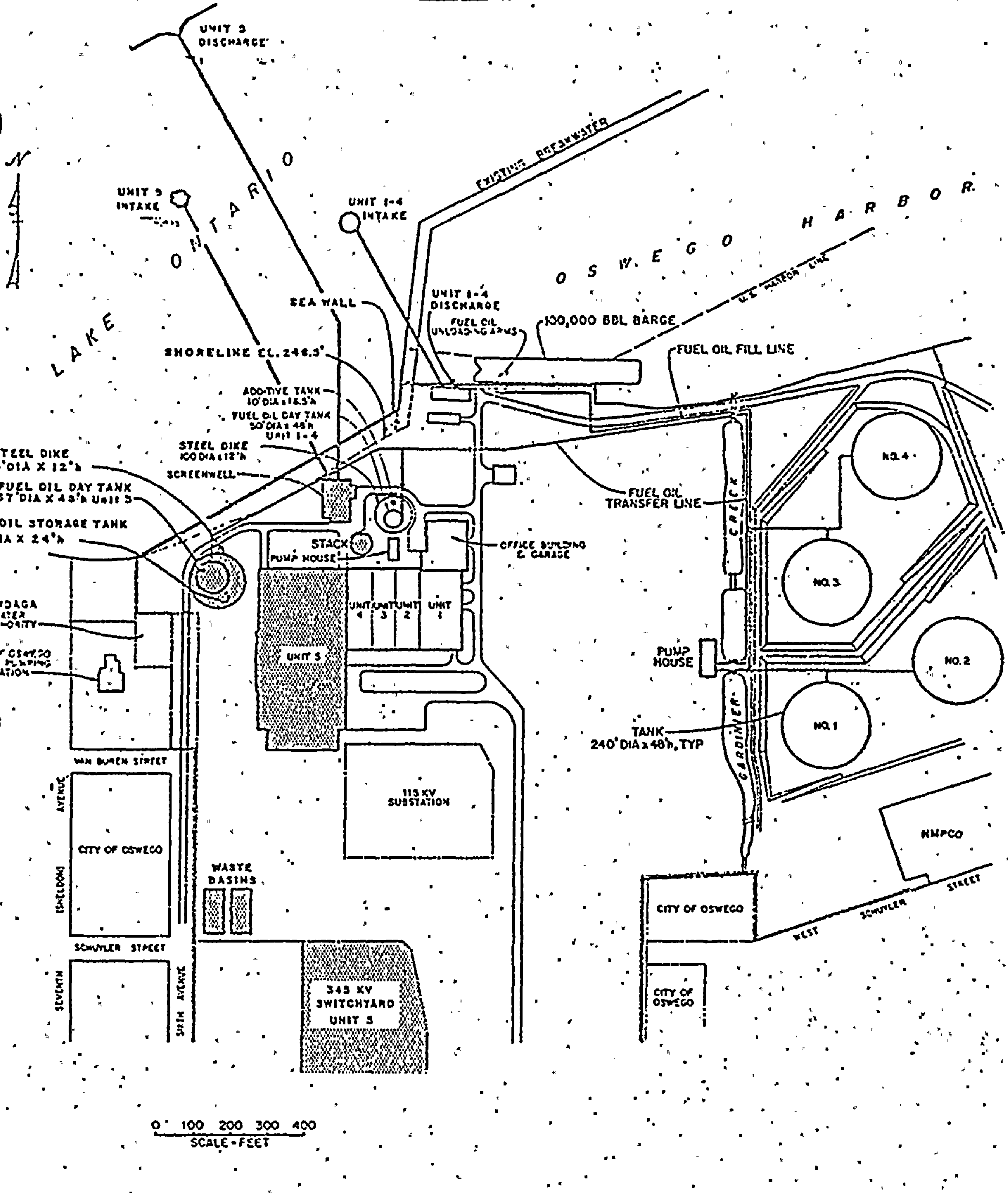
After giving up its heat energy, the steam passes to the single pass steam condenser where it is cooled to its condensation temperature and converted back into water. This water is then raised to a high pressure by the boiler feedpumps for reuse in the steam generator. A portion of the condensate is continuously removed to prevent buildup of solids within the boiler and is replaced with treated lake water.

Circulating water for Unit 5 is taken from Lake Ontario via a submerged inlet, circulated through the condensers, and returned to the lake through a submerged jet diffuser. Figure II-3, shows the locations of intake and discharge structures in Lake Ontario. The intake structure is hexagonally shaped and is located approximately 850 ft from the existing shoreline.



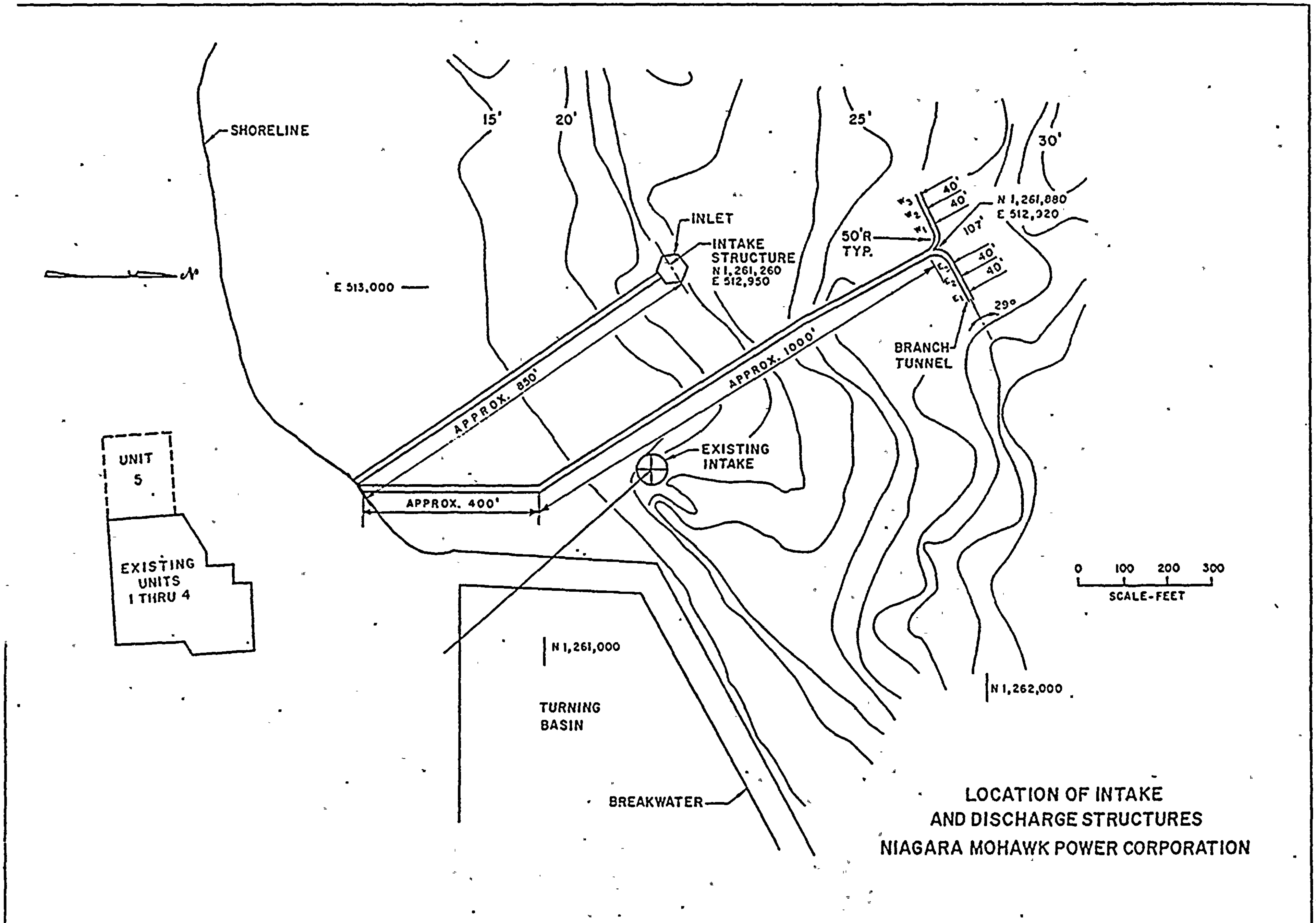
GENERAL LOCATION MAP
NIAGARA MOHAWK POWER CORPORATION

FIGURE II-1



PLOT PLAN

OSWEGO STEAM STATION UNITS 1, 2, 3, 4 & 5
NIAGARA MOHAWK POWER CORPORATION



LOCATION OF INTAKE AND DISCHARGE STRUCTURES
NIAGARA MOHAWK POWER CORPORATION

FIGURE II-3

At the low water datum of 243 ft (International Great Lakes Datum, 1955), the water is 22 ft deep and the clearance between the top of the intake structure and the water surface is 12 ft. Details of the intake structure are shown in Figure II-4.

The pertinent dimensions of the intake structure include a 3 ft sill at the bottom to prevent silting of the intake, a 2 ft roof thickness, and a 5 ft high by 21.17 ft aperture on each of the six sides. The intake aperture is equipped with heated bar racks to prevent the formation of frazil ice. The intake is designed so that the horizontal approach velocity is 1.0 ft per second (fps) when the generating unit is operated at maximum output. There is negligible vertical approach velocity.

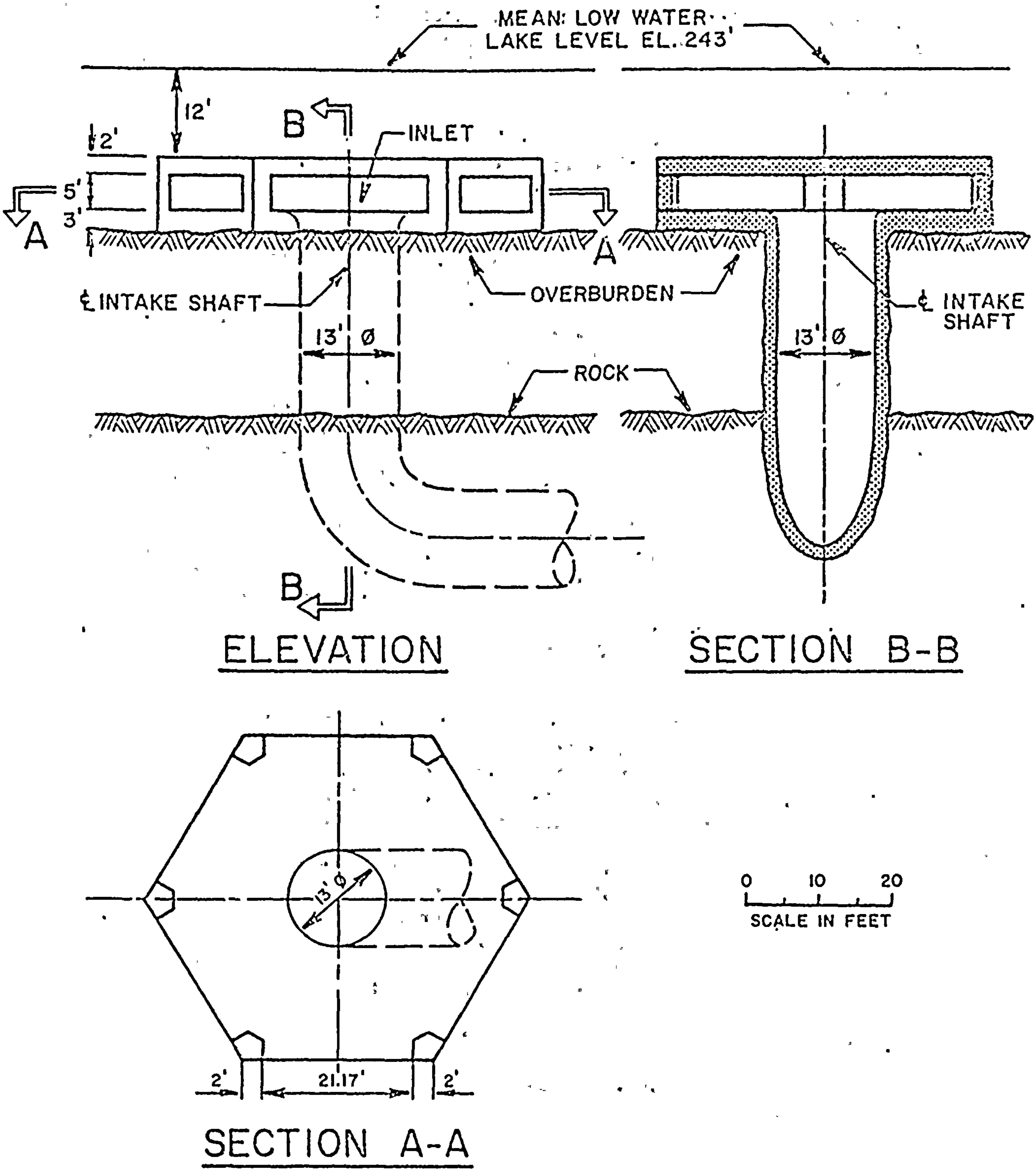
The discharge diffuser is located 1,360 ft offshore in 27 ft of water, and is oriented nearly parallel to the east-west line of the existing breakwater. As shown in Figure II-5, each branch tunnel has three vertical steel risers spaced 40 ft apart. These risers extend through a vertical rock shaft and terminate in a diffuser head. Each diffuser head consists of two horizontal discharge nozzles, 2 ft in diameter at the tip, diverging at a horizontal angle of 20 degrees, Figure II-6.

Circulating water is discharged from 12 nozzles at an initial discharge velocity of 16.8 fps. The relatively high velocities in the nozzle, as compared to those in the branch tunnel, in conjunction with the symmetrical geometry of the diffuser head, produces equal flows from all nozzles. Port centerlines are elevated 5 ft above the lake bottom to minimize bottom scour. The average depth to the nozzle centerline is approximately 22 ft.

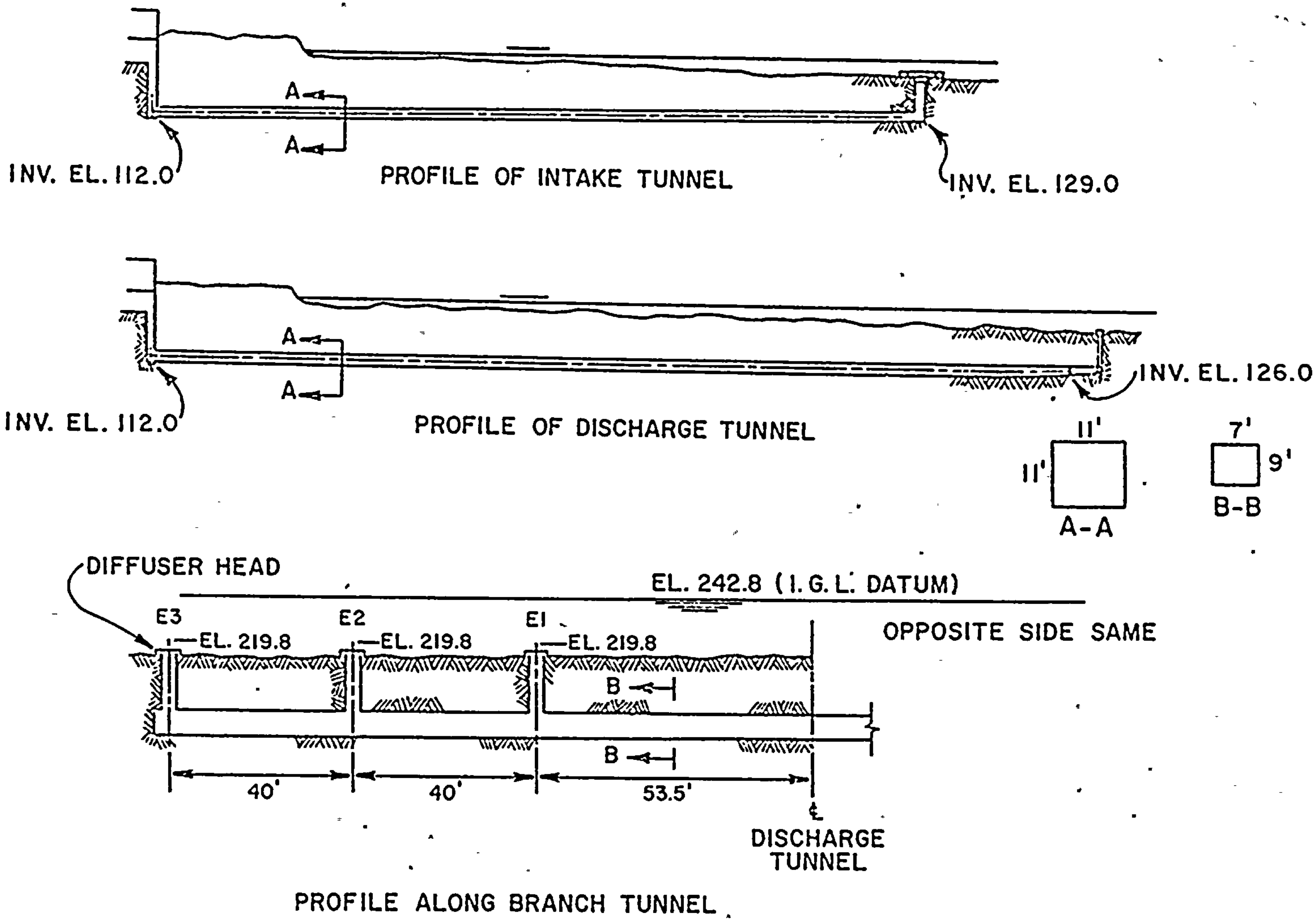
Intake and discharge tunnels pass through rock approximately 100 ft below the lake bottom to a screenwell and pumphouse located onshore. Circulating water pumps withdraw water from the bays in the pumphouse. This structure also contains trash racks and traveling screens located in front of the condenser circulating water pumps.

Oswego Unit 5 requires a total circulating water flow of 635 cubic feet per second (cfs) when the plant is operating at maximum gross output of 890 MWe. The temperature of the condenser cooling flow of 546 cfs is raised 32.4°F while service flow of 89 cfs is raised 5°F. Thus, 635 cfs is discharged from the unit at a maximum temperature rise above lake ambient of 28.6°F. Total heat emission to the lake is 4.09 billion BTU per hour.

For any given load, the thermal efficiency varies with ambient air temperature and circulating water temperature. For example, with turbine valves wide open and operating at five percent over pressure, the calculated heat rates are:

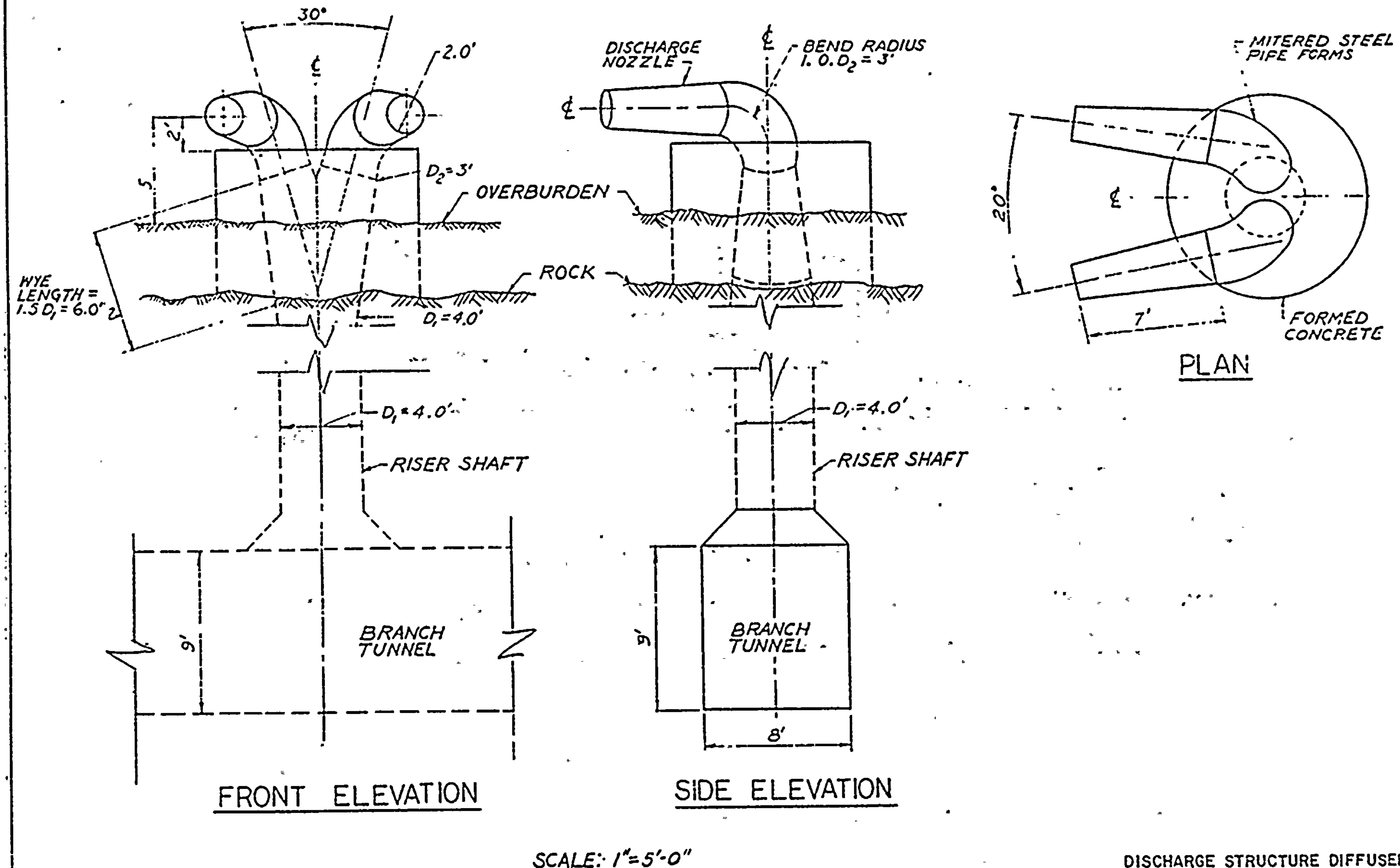


INTAKE STRUCTURE
NIAGARA MOHAWK POWER CORPORATION



TUNNEL PROFILES
NIAGARA MOHAWK POWER CORPORATION

FIGURE II-5



DISCHARGE STRUCTURE DIFFUSER HEAD
OSWEGO STEAM STATION Unit 5
NIAGARA MOHAWK POWER CORPORATION

FIGURE II-6

Circulating Water Inlet Temp. °F	Ambient Air Temp. °F	Unit Heat Rate BTU/KWHR
35	50	9238
45	50	9231
55	50	9221
65	50	9253
55	20	9252

The unit heat rate can be directly converted to thermal efficiency. The average thermal efficiency of the unit is approximately 37%. The heat energy which is not transformed into useful work on the turbine is dissipated to the atmosphere through the stack and to the lake through the circulating cooling water. The energy dissipation is generally divided as follows: 25% through the stack and 75% to the lake.

The total heat delivered to the lake is a function of electrical load and can be quantified by the multiplication of flow and temperature difference. Table II-1 lists the level of heat discharge to the lake as a function of unit load. The dispersion of the thermal discharge in the receiving water body is abetted by the underwater diffusers. The shape of the thermal plume for the case of maximum load and average load is discussed in later paragraphs. However, it is important to recognize that the thermal stress on the biological community in the receiving water body is a function of load, and that the prediction of the impact of the thermal stress applied to the water body is dependent upon the prediction of the variation of the load.

Based on the generation planning and the predicted cost of generation, it is possible to predict with some degree of precision the generation year for the next decade during which Oswego Unit 5 will produce a maximum number of total kilowatt-hours of power. It has been determined through computer studies for this demonstration that the year of maximum usage for Oswego 5 is 1981.

As a part of the above computer study, Niagara Mohawk also determined the average seasonal loads for the Oswego Unit 5 in the year of maximum usage, 1981. The load factors are shown as a percentage of maximum load, unit output, heat discharge to the water body, condenser T (°F), and discharge ΔT (°F) on Table II-2. The seasonal average loads establish the long-term average thermal stress on the water body. However, loads fluctuate daily, and at time of peak load, Oswego Unit 5 may approach maximum power output and establish a high, though transient, thermal stress upon the water body. The frequency of occurrence of the predicted maximum power output has been computed and is identified by season in Table II-3.

TABLE II-1

OSWEGO STEAM STATION - UNIT NO. 5

COOLING WATER CHARACTERISTICS

Oswego Unit 5 Constants: Intake Velocity - 1 fps
Rate of Cooling Water Flow - 546 cfs
*Rate of Total Water Discharge - 635 cfs

Unit Load %	Unit Output MWE	Heat Discharge Billion BTU/Hr.	Condenser ΔT (1) (°F)	Discharge ΔT (°F)
25	208	1.177	9.6	9.0
50	434	2.146	17.5	15.8
75	654	3.030	24.7	22.0
100	855	3.876	31.6	27.8
	890	4.09	32.42	28.6

(1) Maximum; Seasonal variations are less than 1°F, accounting for a circulating water temperature range of 35-75°F, and an ambient air temperature range of -20 - 100°F.

* Service water flow 89 cfs.

TABLE II-2

AVERAGE SEASONAL LOADS

OSWEGO UNIT 5

1981

Season	Percentage Max. Load	Unit Output MWE	Heat Discharge (Billion BTU/Hr)	Condenser T (°F)	Discharge T (°F)
Summer	53.4	453.9	2.244	18.3	16.4
Fall	70.2	596.7	2.765	22.5	20.0
Winter	48.7	414.9	2.052	17.4	15.7
Spring	30.0	255	1.443	11.8	10.8

TABLE II-3

SEASONAL

LOAD VARIATION

1981

Season	Percent of Hours Load Exceeds Designated Levels			
	807 MWE (95%)	765 MWE (90%)	680 MWE (80%)	638 MWE (75%)
Summer	0	0	0	5.95
Fall	35.7	35.7	41.65	41.65
Winter	0	0	5.95	29.76
Spring	0	0	0	0
Annual Cumulative	8.925	8.925	11.9	19.34

Although the Niagara Mohawk generating system is nominally a winter peaking system, the highest loads occur in the mid-December period of late fall. It is also normal practice for base loaded nuclear and coal stations to conduct periodic maintenance in the fall. As a result, the seasonal load for Oswego Unit 5 is highest during the fall of the year. It should also be noted that the spring load factors are extremely low--30% average with peak loading never reaching 75% at any time.

C. CHEMICAL WASTES

The chemical wastes of the station are effectively treated before discharge by Niagara Mohawk through compliance with NPDES permit chemical discharge limitations. The concentrations of chemical wastes after dilution with the cooling water are minimal and hence quantitative evaluations of chemical discharges are not discussed as a part of this demonstration.

III. BASELINE HYDROGRAPHIC CHARACTERISTICS

A. INTRODUCTION

The circulating water system of Oswego Unit 5 is designed to minimize the station's impact on Lake Ontario and to comply with New York State water quality standards and thermal criteria. The design criteria included Lake Ontario temperature and circulation, the particular topography, ambient temperature patterns and currents at the site, and the existing water uses near the site. These features of the Oswego site are reviewed in this chapter to provide a hydrographic description of the site which is used to determine water body segments to be utilized in the assessment chapter of this report. The basis for the selection of the segments is hydrographic in this chapter but biological information presented in chapters VI and VII further supports the selection of these segments.

B. GENERAL FEATURES OF LAKE ONTARIO

1. General Seasonal Temperature Structure

a. Spring Warming and the Thermal Bar

Lake Ontario is a large temperate lake which experiences seasonal changes in its thermal structure. Heating of the lake begins roughly in mid-March and lasts until mid-September. The onset of heating is indicated by the rise of surface water temperatures, particularly in the shallow littoral zones where the temperature rises more rapidly than in regions just offshore. By May this difference has created a sharp horizontal temperature gradient with inshore water temperatures above 4°C (39°F) and the offshore water below 4°C(39°F). The transition zone is a convergence zone where water from the warmer inshore region mixes with the colder offshore water(Rodgers, 1966). As a consequence of the nonlinear temperature/density relationship of fresh water, the mixed water produced in this transition zone is heavier than the water on either side and sinks; setting up a vertical circulation. The transition zone which acts as a thermal bar and which inhibits the free exchange of water between the shallow littoral zone and the deeper part of the lake, moves gradually and steadily offshore with spring warming of the lake until it dissipates in late June. It is estimated that the spring thermal bar may exist for as long as 8 weeks (Sweers, 1969).

During the movement by the thermal bar the inshore water continues to heat up and a thermocline develops which separates the warm surface water from the cold deep water. The thermocline restricts vertical mixing to the epilimnion; but in mid-lake on the offshore side of the thermal bar the mixing can and does extend from surface to bottom. Four weeks after emergence of the bar the inshore area constitutes roughly half the area of the lake (Sweers, 1969).

b. Summer Stratification

The disappearance of an offshore surface temperature minimum in late June can be used to define the start of the summer season in the lake. In general, vertical stratification is established over the entire basin by the combined effects of lake heating and the advection of the warmer near-shore water. The sporadic appearance of surface temperature minima during summer are related to upwelling episodes. As heating continues, stratification intensifies, and the thermocline is more sharply defined with vertical temperature gradients in excess of 1°C/m (0.6°F/ft). As a consequence of stratification, heat transfer and mixing are confined largely to the epilimnion. The lake's mean surface temperature reaches 21°C (69.8°F), and the hypolimnion temperature varies with depth, ranging between 3.8 and 4.0°C (38.0° and 39.2°F) (Sweers, 1969). The thermocline forms near the surface in early summer but descends due to continued heating and reaches a characteristic depth of approximately 21 m (70 ft) (Casey, Fosher, and Klevena, 1965).

c. Fall Cooling

In late September the heating process is reversed, the lake mean surface temperature rapidly drops below 17°C (62.6°F) and the rate of descent of the thermocline increases. The intensity of the maximum vertical temperature gradient decreases as the surface layer and deeper water effectively mix. This process is the consequence of convection caused by cooling at the surface and is enhanced by the weakening of the thermocline which permits wind-induced turbulence to extend to greater depths.

In some respects the fall cooling events resemble the spring warming. When near-shore waters cool below the temperature of maximum density, a "reverse" thermal bar develops separating colder inshore water from warmer offshore water. The fall thermal bar has a weaker thermal gradient than the spring thermal bar and inhibits horizontal mixing to a lesser extent.

d. Winter Cooling

The breakdown of stratification throughout the lake marks the onset of the winter season. The main offshore water mass is well mixed, attaining a nearly isothermal condition. The precise date of overturn differs from year to year depending on the incidence of storm passage. The lake surface is cooled to below 4°C(39°F) and surface isotherms tend to be parallel to shore. As cooling continues and surface temperatures decrease below 4°C (39°F), the vertical stratification is again described by a thermocline with colder buoyant water above the warmer 4°C (39°F) water at depth. Vertical circulation at times extends as deep as 100 m (328 ft) (Sweers, 1969). With continued

cooling ice forms in the near-shore region. Under normal conditions the greatest extent of ice cover is found in the east end of the lake in mid-March. In a severe winter ice covers about 25% of the lake surface (U.S. Army Corps of Engineers, 1975).

2. Lake General Circulation

In its simplest form the large scale general circulation of Lake Ontario is observed to be counter-clockwise (cyclonic flow) with flow to the east along the south shore in a relatively narrow band and somewhat less pronounced flow to the west along the north shore. The conceptual model that explains this average circulation is presented here with a minimum of detail.

A cool mound of water is found to extend from surface to bottom in spring and from below the thermocline to the bottom in summer and fall (Sweers, 1969). The baroclinic flow resulting from the horizontal temperature differences is initially directed outward from mid-lake towards the shore, although the coriolis effect is acting to turn the flow to the right (clockwise) its effect is diminished due to bottom friction. This outward flow brings water to the inshore area where it begins to pile up. A surface slope, higher inshore than in mid-lake, develops into a barotropic current initially directed lakeward. The barotropic current tends to the right because of the coriolis effect. The result is that coriolis effect and the barrier effect of the coastline trap the flow against the shoreline. The flow continues along the shoreline in a counter -clockwise direction as long as the surface slope is maintained.

Inflow from the Niagara River causes the western end of the lake to be higher than the eastern end (on the average). The resulting flow down the gradient is held against the lake's south shore by the coriolis effect, thereby enhancing the already existing barotropic flow along the south shore. Wind stress averaged over the year tends further to accelerate the flow to the east and decelerate the flow to the west.

The general circulation in winter is less well documented. In late fall after overturn has occurred, the lake is essentially isothermal, thereby permitting a freer exchange of water from surface to bottom. Average wind direction in winter is primarily from the west-northwest. The net surface flow that results is eastward with westward return flow developing below the surface. The surface layer in the western end is advected to the east and is replaced by subsurface water (Sweers, 1969). This large scale upwelling at the upwind end of the lake and downwelling at the downwind end mixes the surface and subsurface water on a scale that is not likely to occur during the rest of the year.

Conservative pollutants that are limited to the upper layer during the time of a well-developed thermocline are diluted when the hypolimnetic water is made available for mixing. In spring, with the development of the thermocline, the bottom water is again partially insulated from the surface layer.

The general circulation described above is documented by observations collected over long periods (months). The circulation patterns that are observed at any given time, however, are more complex as a result of the transient wind distribution and the lake's response to the non-steady wind. Sometimes a major wind shift can alter the currents in a matter of hours, while at other times some features of the current pattern have continued even with an opposing wind (Csanady, 1972a). One measure of the response time of the currents to a shift in wind distribution is partially related to the scale of the current; large features such as the coastal jet respond more sluggishly, whereas nearer to shore the response is seen to be more rapid, six hours or less. Additionally, the deeper the current, the more slowly it responds. A shift in the currents as a result of wind changes eventually changes the lake surface slope and the temperature field, forcing an alteration in much of the lake's circulation pattern.

3. Perturbations of the General Circulation Pattern

Two particular examples of wind-induced changes in the general circulation are upwelling and internal oscillations. Upwelling occurs when a water mass is forced toward the surface and it occurs to some degree in all lakes during all seasons (Mortimer, 1971). It is most conspicuous during seasons of stratification when the upwelled water is much colder than the surface water that it displaces. Wind stress and associated currents depress the thermocline to below equilibrium level at the downwind end of the basin, while at the upwind end the thermocline is displaced upward and may intersect the surface. The upwelling motions are strongly modified by the coriolis force with the result that depression of the thermocline is greatest to the right of the downwind end of the basin and upwelling is strongest to the left of the downwind end (Mortimer, 1971). For example, in Lake Ontario, a west wind causes upwelling along the northwest shore, and the thermocline is deepest along the southeast shore.

A variety of mechanisms have been proposed to account for the observed periodic displacement of the thermocline. The most direct explanation is that an upwelling event displaces the thermocline from equilibrium by converting kinetic energy of the wind to potential energy of the thermocline postion. When the wind stress is removed, internal waves are set in motion and contribute to the dissipation of this energy. Internal waves increase in amplitude after storms, and in Lake Ontario the oscillations have a period near 17.5 hours, roughly three complete

oscillations every two days. These oscillation events are a regular feature of lake temperature records and are prominent in the intake temperature records at many power plants.

C. SITE FEATURES

1. Topography and Geology of the Lake Bottom

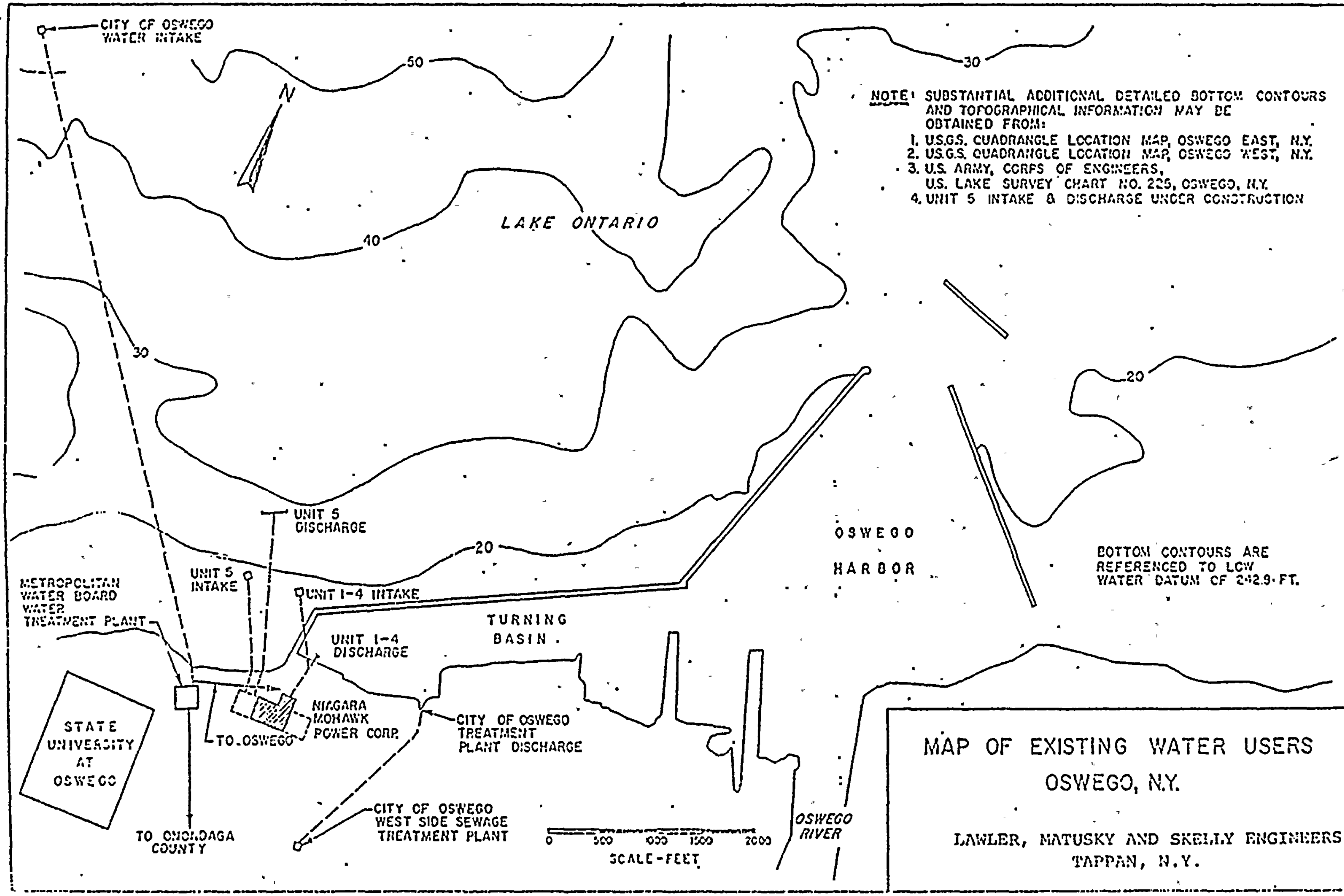
A description of the topography and geology of the lake bottom in the vicinity of the station was compiled from borings, fathometric surveys, and direct observation by divers. Figure III-1 shows the shoreline and lake bottom contours in the vicinity of the Oswego Steam Station as determined by a fathometric survey. To the west of the Steam Station the lake shore is in a near natural condition and the lake bottom shelves gradually to a depth of about 12.1 m (40 ft) at a distance of 610 m (2,000 ft) from shore. East of the steam station the breakwater cuts off the natural shoreline, and although the breakwater is, for the most part, simply a rough pile of large rocks, its face is precipitous and the depth at the foot of the breakwater is between 5.5 and 7.6 m (18-25 ft).

Direct observations of the lake bottom were made by divers, and these observations indicated that the lake bottom west of the Oswego Steam Station is fairly consistent in character, being generally composed of flat rock and completely free of sediment.

A large number of rhombiodal slabs of broken-off bedrock, with dimensions of roughly 1.2m by 1.5 m (4 ft by 5 ft), are located in the near-shore area to a depth of 3 m (10 ft). Most of the area, however, is made up of dense glacial till, forming a series of steps extending progressively out into the lake, each bed or step of different depth ranging from a few inches to more than a foot. The bottom is strongly fractured or jointed with some erosion taking place in the cracks.

In the 3-6.1m (10-20 ft) depth, the loose slabs and the wider cracks gradually become less evident so that at the 6.1 m (20 ft) depth, the bottom is almost exclusively smooth. At this depth, a number of rounded boulders and small pieces of flat rock can be found. Beyond the 6.1 m (20 ft) depth, the bottom is similar, with patches of loose rock and sand intruding in places.

Immediately west of the steam station is a section of the lake similar to a bay. In this area, the lake bottom is composed primarily of rounded boulders up to 0.3 m (12 inches) in diameter. Beyond a depth of 2.1m (7 ft), the lake bottom is similar to that described above with a sandy



MAP OF EXISTING WATER USERS
OSWEGO, N.Y.

LAWLER, MATUSKY AND SKELLY ENGINEERS
TAPPAN, N.Y.

FIGURE III-1

bottom occurring beyond the 6.1 m (20 ft depth). The sand is, for the most part, a thin skin over the glacial till.

East of the steam station, the breakwater acts as the lake shoreline until the harbor entrance is reached. The breakwater is composed of rocks which slope down into the lake at about a 45° angle. Lakeward of the base of the breakwater, the bottom consists of an apron of large flat-sided rocks 1.2 x 1.5 x 1.5m (4 ft x 5 ft x 5 ft). Sand is also found on the bottom in this area. The rock apron extends only a short distance out into the lake about 9.1m (30 ft), beyond which the lake bottom is swept clean. Near the eastern end of the breakwater adjacent to the mouth of the river, considerable amounts of sand appear to have been deposited.

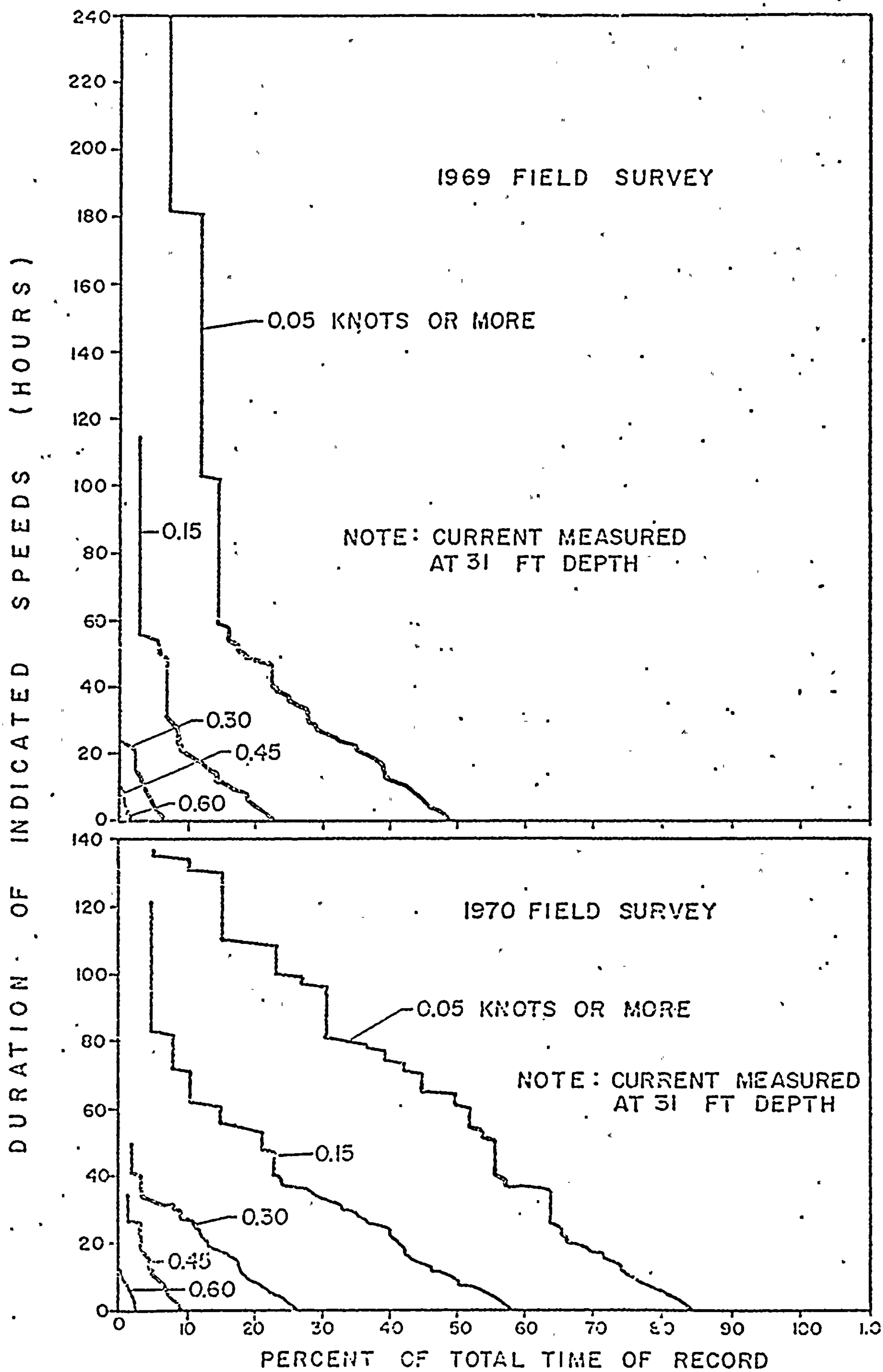
In addition to the direct observations made of the lake bottom by divers, borings were taken in the lake bottom from a point just offshore of the steam station out to a distance of 457m (1,500 ft) in the lake. The analysis of the boring samples confirmed that an overburden of varying thickness forms the lake bottom beyond a depth of approximately 2.1m (7 ft) and that rock forms the lake bottom in shallower depths. Generally, the area is characterized by patches of loose sandy silt varying in thickness from a few centimeters to as much as 0.6m (2 ft), overlying a dense glacial till. The glacial till is a preconsolidated heterogeneous mixture of gray-brown silt, sand, gravel, and boulders. The bedrock in the area is Oswego Sandstone.

2. Local Currents

Current measurements have been made at both the Nine Mile Point (Fitz-Patrick) and Oswego power station sites. The more extensive data were obtained at Nine Mile Point.

In the course of preoperational studies for the James A. FitzPatrick Nuclear Power Plant, current measurements were made off the Nine Mile Point promontory from May to October 1969, and July to October 1970. Two fixed underwater towers were placed in the lake, one in 7.3 m (24 ft) of water, and one in 14.0 m (46 ft) of water. The instruments provided average hourly current speed and direction. In addition, two drogue surveys were conducted in 1969 to obtain the overall current pattern at the site. These studies were reported by Gunwaldson et al. (1970) and PASNY (1971). Figure III-2 presents frequency-duration data derived from these studies. The data obtained are consistent with wind current frequencies reported by Palmer and Izatt (1970) for a similar water depth near Toronto.

DURATION OF LAKE ONTARIO CURRENT



The field data clearly illustrate a correlation between summer currents and wind speed. The correlation is an accepted principle of hydrodynamics as theorized by Ekman (1928) and subsequently verified by numerous oceanographers (Neumann and Pierson, 1966). Measurements of wind currents at lightships (Haight, 1942) have been analyzed to determine the ratio of current speed to wind speed. Reported values of this ratio, commonly called the "wind factor," range between .005 and .030.

The wind speed frequency data indicate that over the year a speed in excess of 32 km/hr (20 mph) occurs 21.6% of the time based on readings averaged over a 6-hour period. For the summer months, June through September, winds in excess of 32 km/hr (20 mph) occur 13.9% of the time. The current speed of 6 hour duration exceeded with comparable frequency in 14 m (46 ft) of water is about 15 cm/sec (0.5 fps) (see Figure III-2). For a persistence of 24 hours, the current speed exceeded 13.9% of the time is 13.7 cm/sec (0.45 fps).

The predominant direction of currents in the studies described above is alongshore, as dictated by continuity. On those occasions when onshore or offshore currents were observed, their magnitudes were substantially less than those for alongshore currents. The reported frequencies of various current directions during the summer are presented in Figure III-3. This figure indicates that currents alongshore from the west or east are equally frequent at 35% of the time for each. Onshore and offshore currents each account for 5% of the observations. The remaining 20% of the observations were below the meter threshold, 0.05 knots (2.5 cm/sec, 0.09 fps). At the 6.4 m (21 ft) depth in 14.0 m (46 ft) of water the mean onshore current speed was 3.0 cm/sec (0.09 fps) and the mean offshore current speed was 6.0 cm/sec (0.2 fps). On the other hand, longshore currents from the west and east averaged 9 cm/sec (0.3 fps).

Typical longshore currents from east or west were thus double the current speeds observed for onshore or offshore currents, with the offshore currents being generally faster.

Vertical profiles of currents have been recorded in several lake studies. Current profiles with depth, however, are sensitive to the turbulent momentum exchange coefficient and ambient stratification. A theoretical profile was computed for the homogeneous shallow waters found near the Nine Mile Point site and indicates the absence of any significant Ekman spiral.

Lake currents were measured at selected locations in the immediate vicinity of the Oswego generating station on five days between 12 October and 19 November 1970. These surface current velocities were mostly longshore with speeds that ranged from very low (less than 2.5 cm/sec, 0.08 fps) up to 15 cm/sec (0.50 fps). This is in general agreement with the measurements at Nine Mile Point.

LAKE ONTARIO CURRENT DIRECTIONS

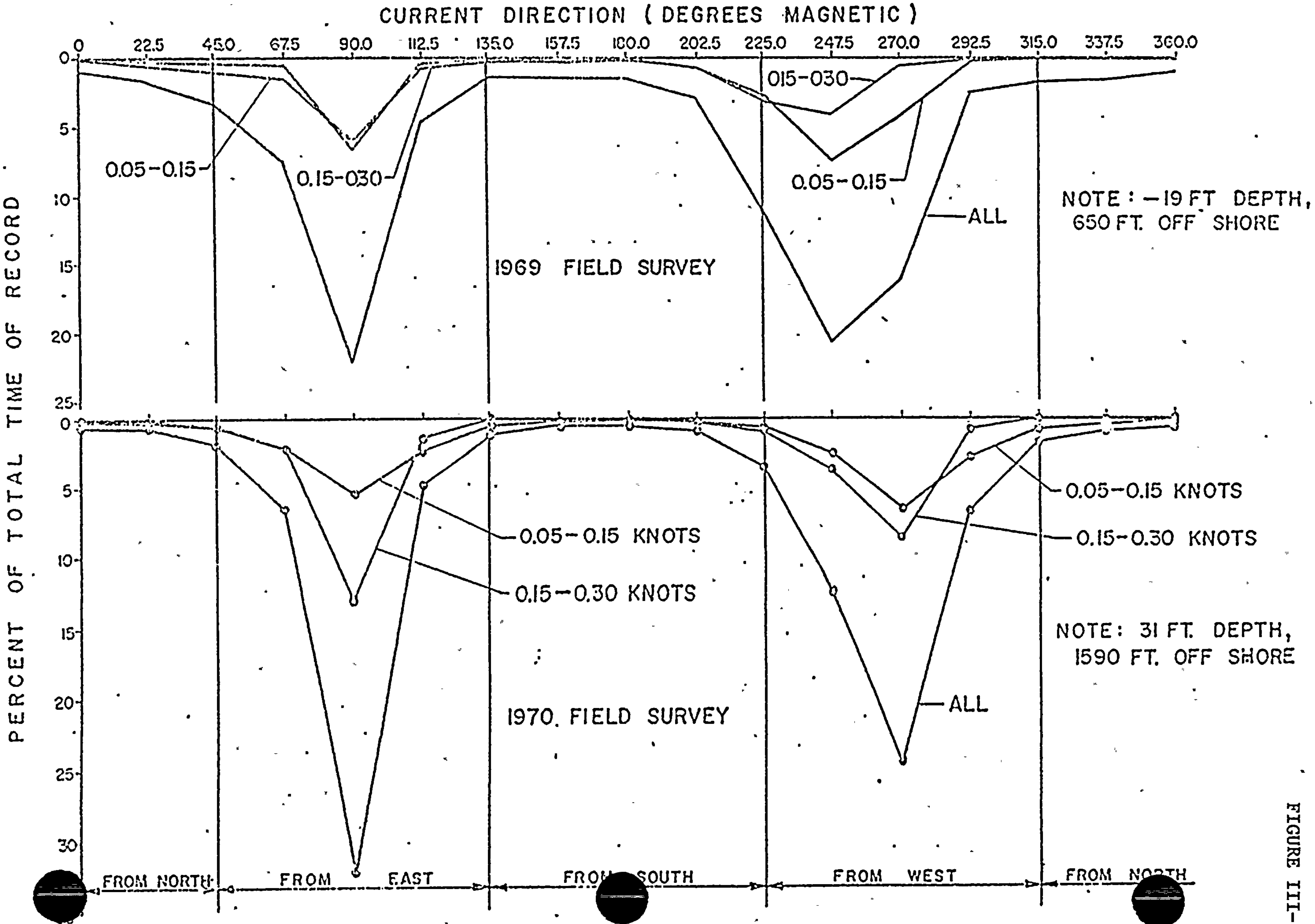


FIGURE III-3

The Oswego Unit 5 intake is designed to withdraw up to 17.98 m^3/sec (635 cfs) of lake water at full capacity. The water will be drawn from a layer that is between 1.5 m (5 ft) thick (the height of the intake opening) and the total thickness of the water column from surface to bottom (8.6 m, 28 ft). If it is assumed that a longshore current is present at a characteristic speed o 5.2 cm/sec (0.17 fps), then in the extreme case of strong stratification, the required net flow.

Local Lake Thermal Structure

Data on the thermal structure of the lake in the vicinity of Oswego were available from studies conducted offshore of the James A. FitzPatrick Nuclear Power Plant during 1969 and 1970, from temperature data recorded in the existing intake for Oswego Units 1-4 from 1968 through 1972, and from studies conducted offshore of the Oswego-Nine Mile Point area during 1973. A short description of each of these studies is presented in subsequent paragraphs. These data were used to determine the vertical temperature variations and the surface temperatures in the vicinity of Oswego.

In conjunction with the lake current studies carried out in 1969 and 1970 as part of the preoperational surveys for the James A. FitzPatrick Plant (PASNY,1971), observations were also made of water temperatures. Three types of temperature measurements were made. These included:

- intermittent vertical profiles obtained in 18.3m and 30.5m (60 and 100 ft) of water,
- continuous temperature recordings, using seven self-contained underwater instruments mounted on the two underwater towers, obtained at various depths, and
- surface temperatures measured by airborne infrared radiometry.

The 1970 studies offshore of Oswego consisted of collection of weekly temperature at four locations in the vicinity of the discharge location of Oswego Unit 5. Temperature measurements were made at 1 meter increments from surface to lake bottom. These measurements were made for seventeen consecutive weeks from July through November 1970 (QLM, 1971).

Temperature data in the Oswego-Nine Mile Point area were obtained during 1973 from west of Oswego to east of Nine Mile Point. Vertical temperature profiles were obtained weekly from June through mid-December 1973 along five transects (QLM, 1974a).

Data from these studies were used to evaluate the vertical temperature structure and to determine whether or not persistent stratification exists near the Oswego site. Vertical temperature profiles revealed the existence of transient thermal gradients equal to or greater than 1°C per meter (1.6°F per 3.2 ft) throughout the study area. The gradients appeared to be seasonal since they existed primarily in the summertime. They were not "seasonally stable," since they were generated and destroyed by surface heating and cooling and mixing within the water column over periods dependent upon meteorological conditions. Although gradients were observed on sequential weeks for up to a three week period, the gradients observed were at different temperatures and at different depths from week to week and, therefore, were not persistent. In addition, when the gradients were observed, they appeared to be uniform from station to station. A more complete discussion is presented in the documents previously submitted to the EPA.

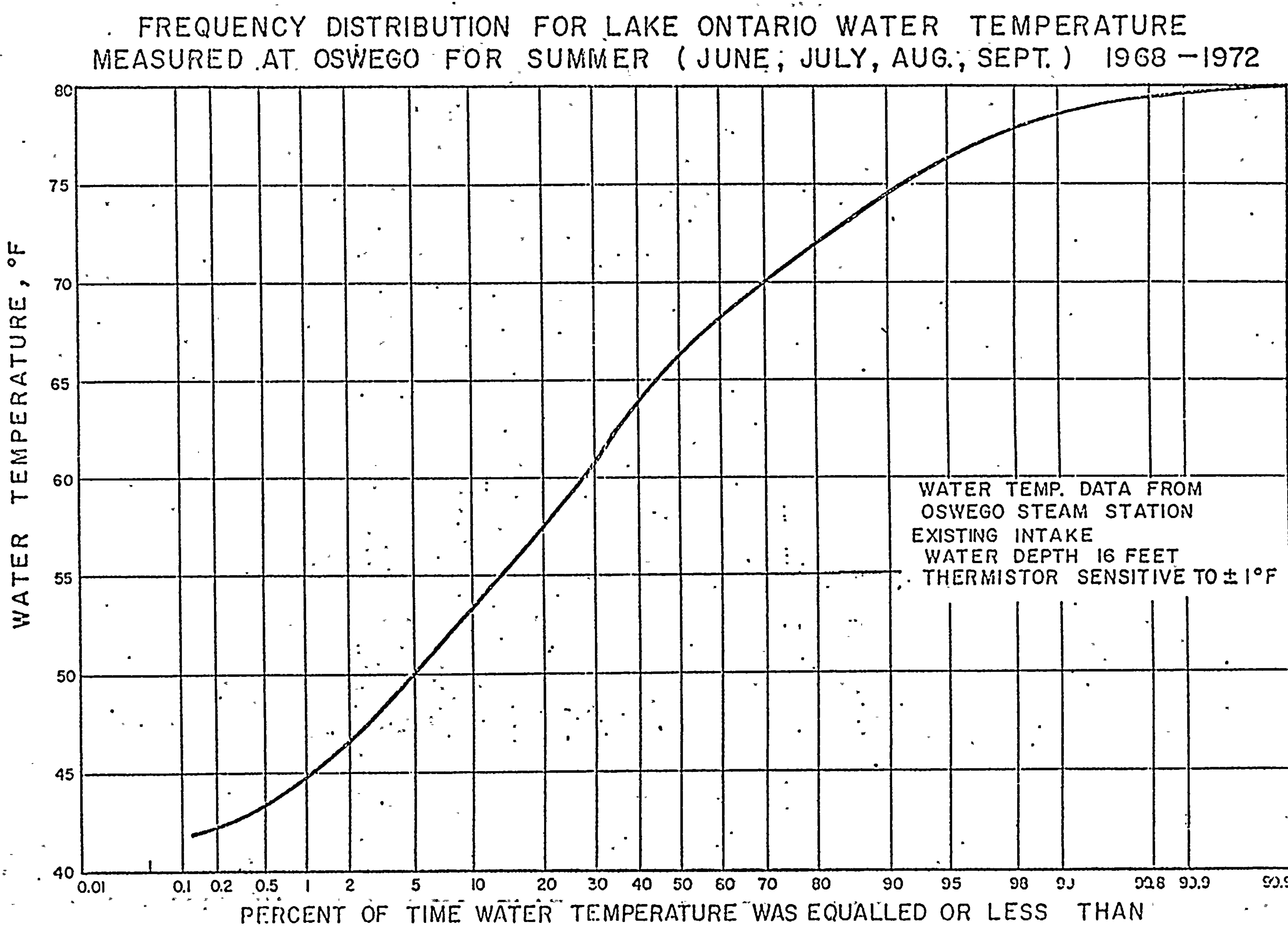
These data were also used to determine the surface temperature in the Oswego area. During 1970 the maximum surface temperature recorded was 25.5°C (77.9°C). The temperature data recorded in the existing intake of the Oswego Steam Station were statistically analyzed and are shown in Figure III-4. Since the lake is generally isothermal in the top 6m (20 ft), the temperature obtained at the intake depth of 4.9m (16 ft) may be considered to be representative of the surface water temperatures. The analysis shows that, for the summer months, temperature in excess of 23.3°C (74°F) occurred only 10% of the time during the summer and less than 1% of the time on an annual basis.

Figure III-5 shows the average surface temperature throughout the 1973 survey period for the stations in water depths of 6 and 30.5m (20 and 100 ft). As shown in this figure, temperatures at both stations were approximately 12°C (54°F) on 4 June, rose to a maximum temperature of approximately 24°C (75°F) on 13 August, and then declined to approximately 6°C (43°F) on 10 December. A drop in the average surface temperatures of between 3°C (5.4°F) and 5°C (9°F) seems to have occurred during the week between 11 June and 18 June. This drop in temperature can be attributed to "upwelling" generated by wind from the south.

D. EXISTING THERMAL ADDITIONS IN THE OSWEGO VICINITY

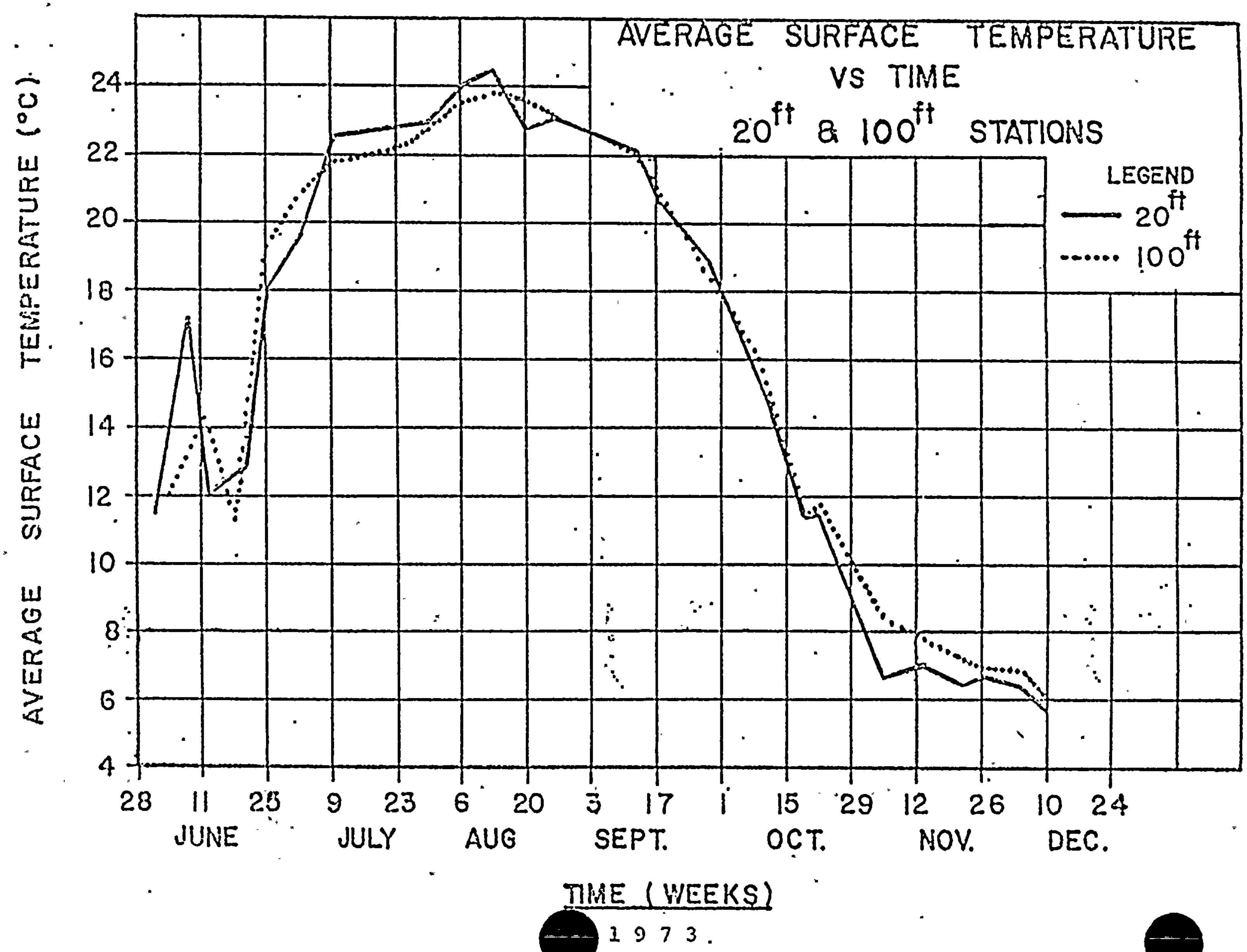
1. Oswego Steam Station Units 1-4

The Oswego Power Plant's Units 1-4 have a maximum output of 407 megawatts. These units were constructed during the period 1938 to 1959.



FREQUENCY DISTRIBUTION FOR LAKE ONTARIO WATER TEMPERATURE MEASURED AT OSWEGO FOR SUMMER (JUNE, JULY, AUG., SEPT.) 1968 – 1972
WATER TEMPERATURE, °F
80
75
70
65
60
55
50
45
40
0.01
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
PERCENT OF TIME WATER TEMPERATURE WAS EQUALLED OR LESS THAN
WATER TEMP. DATA FROM
OSWEGO STEAM STATION
EXISTING INTAKE
WATER DEPTH 16 FEET
THERMISTOR SENSITIVE TO ± 1°F

FIGURE III-4



AVERAGE SURFACE TEMPERATURE
VS TIME
20ft & 100ft STATIONS
LEGEND
20ft
100ft
AVERAGE SURFACE TEMPERATURE (°C)
24
22
20
18
16
14
12
10
8
6
4
28
11
25
9
23
6
20
3
17
1
15
29
12
26
10
24
JUNE
JULY
AUG
SEPT.
OCT.
NOV.
DEC.
TIME (WEEKS)
1973.

FIGURE III-5

The cooling water for these units of up to 21.58m^3/sec (762 cfs), when operating at the maximum capacity ratings, is taken from the lake at a point some 76.2 m (250 ft) north of the northwestern tip of the Oswego Harbor breakwater. This flow is returned to the Oswego Harbor as a thermal discharge, at temperatures up to 6.8°C (12.4°F) higher at the discharge than the intake temperature. The discharge is located in the western leg or "turning basin" of the Oswego Harbor. The circulating system for Oswego Unit 5, with a discharge of 17.98m^3/sec (635 cfs) is independent of the Unit 1-4 system, with the submerged discharge located in the lake rather than the turning basin. Table III-1 shows some of the hydraulic characteristics of the discharge of the existing units compared with Oswego Unit 5.

2. Nine Mile Point Nuclear Station Unit 1

The Nine Mile Point Nuclear Station Unit 1, which has been in operation since 1969 uses a boiling water reactor to produce up to 1850 MWT. This heat is used by the steam turbine-generator to provide 610 Mwe (net) of electrical power capacity.

The maximum cooling water flow of 16.94m^3/sec (597 cfs) for this unit is taken from the lake approximately 259.1m (850 ft) offshore of the site. This flow is returned to the lake as a thermal discharge, at temperatures up to 17.3°C (31.2°F) higher than the intake temperature, through a submerged discharge in the lake. The discharge is located approximately 11.3 km (7 mi) east of the Oswego Unit 5 discharge.

3. James A. FitzPatrick Nuclear Power Plant

The James A. FitzPatrick Nuclear Power Plant, which commenced operation during 1975, uses a boiling water reactor to produce up to 243.6 MWT. This heat is used by the steam turbine generator to provide 821 Mwe (net) of electrical power capacity.

The maximum cooling water flow of 23.36m^3/sec (825 cfs) for this unit is taken from the lake approximately 274.3m (900 ft) offshore of the site. This flow is returned to the lake as a thermal discharge, at temperatures up to 17.5°C (31.5°F) higher than the intake temperature, through a high speed submerged diffuser designed to achieve rapid dilution. The discharge is located approximately 12.1 km (7.5 mi) east of the Oswego Unit 5 discharge.

4. Oswego River

The Oswego River discharges an average flow of 174.17m^3/sec (6137 cfs) (based on the 33-year period, 1933-1967) into the Oswego Harbor from the south; here the flow mixes with the Units 1-4 and waste treatment plant discharges, and enters Lake Ontario at the harbor mouth.

TABLE III-1

DISCHARGE CHARACTERISTICS FOR OSWEGO UNITS 1-4, NINE MILE UNIT 1, FITZPATRICK UNIT AND OSWEGO UNIT 5

	Oswego Units 1-4	Nine Mile Unit 1	Fitzpatrick Unit	Oswego Unit 5
Length of main tunnel from existing shoreline	-	528 ft 160.9 m	1260 ft 384 m	1360 ft 414.5 m
Tunnel velocity	-	8 fps 2.44 m/sec	4.7 fps 1.43 m/sec	-
Length of diffuser	-	-	774 ft 235.9 m	260 ft 79.3 m
Number of diffuser ports	-	-	12	12
Number of diffuser ports/riser	-	-	2	2
Inside diameter of diffuser ports	-	-	2.5 ft 0.76 m	2.0 ft 0.61 m
Port spacing	-	-	150 ft 45.7 m	40 ft 12.2 m
Initial discharge velocity	-	4 fps 1.22 m/sec	14 fps 4.27 m/sec	16.8 fps 5.12 m/sec
Angle between ports	-	-	42°	20°
Total diffuser flow	762 cfs 21.58 m^3/sec	597 cfs 16.94 m^3/sec	825 cfs 23.36 m^3/sec	635 cfs 17.98 m^3/sec
Average depth of port centerline below mean low water	-	16 ft 4.9 m	25 ft 7.62 m	21 ft 6.4 m
Average depth of lake bottom below mean low water at discharge	-	18 ft 5.5 m	30 ft 9.14 m	26 ft 7.92 m
Port temperature rise above lake ambient	12.4°F 6.9°C	31.2°F 17.3°C	31.5°F 17.5°C	28.6°F 15.9°C

- does not apply

The maximum flow on record was 1064.235m^3/sec (37,500 cfs), which occurred on 28 March 1936. The minimum daily flow of 10.02m^3/sec (353 cfs) was recorded on 14 August 1949, but the minimum average seven-consecutive-day flow, having a once-in-ten-year frequency (MA7CD/10) is 20.43m^3/sec (720 cfs).

Previous investigations have shown that temperatures in the Oswego River are normally higher than those at the surface of the lake. The 1970 survey data indicate that the river warms more rapidly than the lake and is warmer throughout the summer months. The draft NFIC report on a thermal survey conducted by infrared radiometry demonstrates such a plume in the lake that results from the river discharge.

E. WATER BODY SEGMENT IDENTIFICATION

1. Rationale for Water Body Segment Selection

It is expected that the effects of power plant operations on the Lake Ontario ecosystem will be seen first in the near field, the area for which the studies which have been conducted by NMPC from 1972 to the present provide the most data. It is possible to delimit a segment of the lake for which data exists and to make appropriate comparisons between measured or predicted effect of power plants and the abundance of the resident or migratory population. The power plant is fixed in location; the population estimates, however, will vary with the location and size of the considered water body segment. The proportional impact

$$\frac{\text{number of affected organisms}}{\text{abundance in water body segment}}$$

will vary with the segment size. For this reason two segments of significantly different volumes have been chosen, water body segment I (WSI) and water body segment II (WSII), illustrated in Figure III-6.

The near-shore circulation is usually not still, but either in a state of calm, steady longshore currents or in a state of transition during which frequent current reversals are observed. Some statistics of this near-shore circulation are presented in Section III-B-2 (Figures III-2 and III-3).

It has been reported (Csanady, 1970; QLM, 1974b) that fluorescent dye released in the near-shore area prior to a current reversal is not always seen to return to the point of discharge, and it is suggested that the current reversal accompanies an exchange of mass. That is, steady longshore currents predominate during the interludes between the periodic naturally occurring flushings of the near-shore zone at which time large masses of offshore water replace the near-shore water and to some extent renew the near-shore populations.

LOCATION OF WATER BODY SEGMENTS I AND II

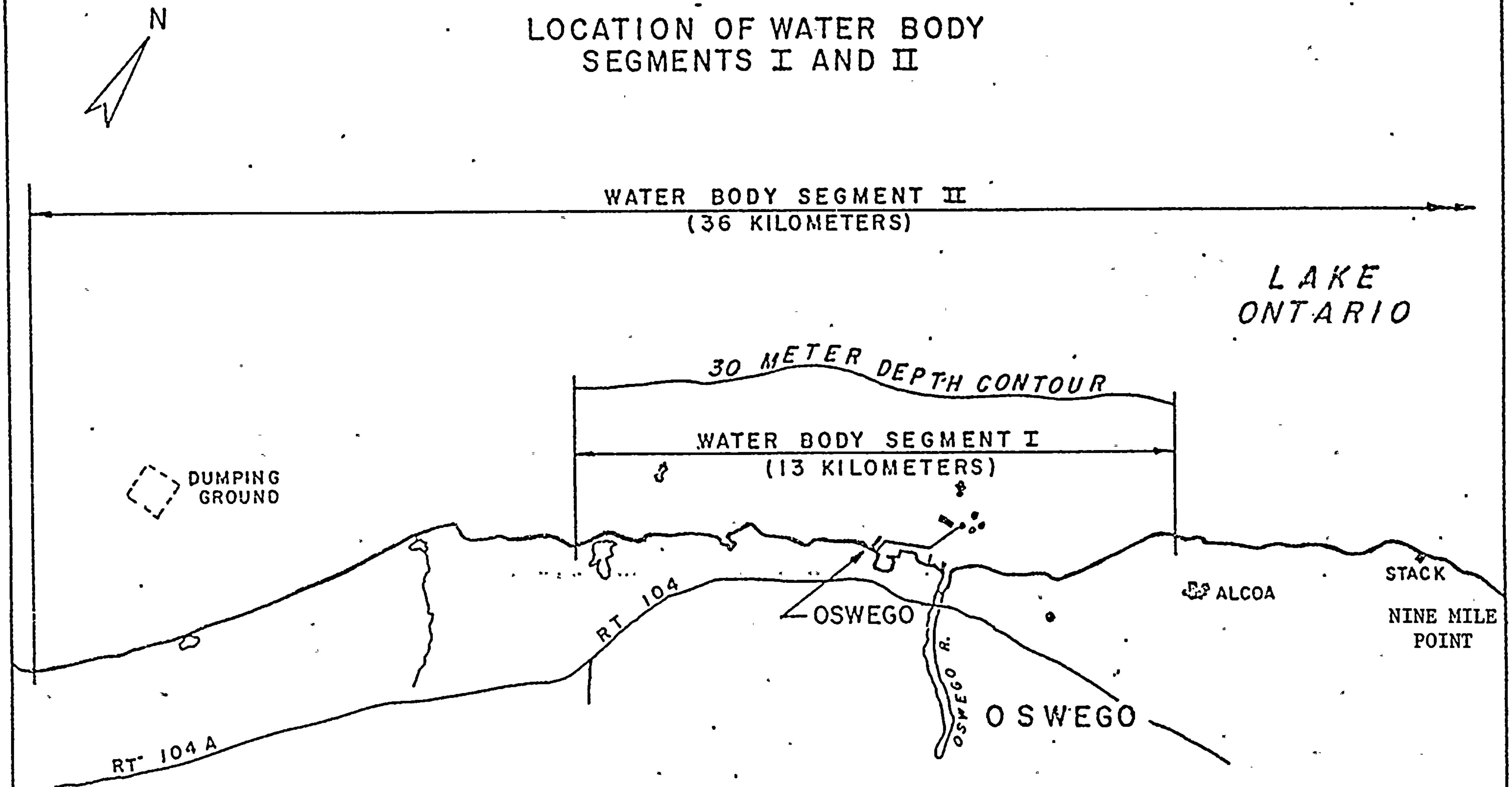


FIGURE III-6

The smallest segment (WSI) is chosen to be of sufficient size to contain the thermal plume and to include expected excursions of floating organisms in the period of time between two naturally occurring flushings of the segment. As the size of a segment increases, the segment abundance increases, and the proportional impact of the power station decreases. When an adjacent operating power plant impact is included in the water body segment, the proportional impact is increased by the increased number of affected organisms associated with the adjacent plant. The second and largest segment (WSII) is chosen to include the plumes and expected excursions for both Oswego and Nine Mile Point plants.

2. Water Body Segment I.

The smaller of the water body segments to be considered for assessment is chosen to contain the entire thermal plume described in Chapter IV. The criteria used for selection of the water body length are based on the persistence of currents measured at a nearby location (Nine Mile Point).

Many investigators (Landsberg, Scott, and Fenlon, 1970; Csanady, 1972a, 1972b; Pickett and Richards, 1974; QLM, 1974c) report current speeds in the very near-shore zone are about 0.1 knots (5.2 cm/sec, 0.17 fps) and their dominant direction is along the shore. This is confirmed by the reported frequencies shown in Figure III-2; consequently, 0.1 knots is accepted as a characteristic near-shore speed. Further, the state of knowledge of these very near-shore currents is that they are persistent only in the alongshore direction and that onshore and offshore flow is associated with large-scale mixing with the main portions of the lake.

The persistence of currents is presented in Figure III-2. It can be seen from this figure that 90% of the currents of speed 0.1 knots (5.2 cm/sec, 0.17 fps) persist for periods less than a day and one-half for a total excursion of approximately 6.5 km (4.1 mi).

The reported frequencies of alongshore currents indicate that both directions are likely to occur. Therefore the segment extends 6.5 km (4.1 mi) in both directions. The offshore extent of the smaller water body segment is chosen to be bounded by the region that frequently contains persistent large-scale lake features, such as the coastal jet.

The coastal jet is reported to be centered about 6-8 km (3.8-5.0 mi) (Csanady, 1972a) from shore; the nearshore edge of this fast-moving current has been reported to be within 4.8 km (2.5-5.0 mi) of shore (Scott, Jekel, and Fenlon, 1971). For this reason the 30 m (98.4 ft) depth contour which extends approximately 3.5 km (2.2 mi) from shore

has been chosen to be a conservative estimate of the offshore boundary. Water body segment I has an approximate surface area of 45.5 km^2 (17.8 mi^2). The volume of water contained within this water body segment is 6.7×10^8 m^3 (2.4×10^{10} ft^3). The cross sectional area through water body segment I normal to the long shore flow has an approximate area of 5.1×10^4 m^2 (5.5×10^5 ft^2). Segment I represents 0.042% of Lake Ontario's water volume of 1626 Km^3 (390mi^3). The characteristics of water body segment I are summarized in Table III-2.

3. Water Body Segment II.

The larger water body segment approximately triples the horizontal dimensions of the smaller water body segment. Based on reported current persistences, it is expected that 95% of the currents of 0.1 knots will have an excursion distance smaller than half the water body Segment II length. That is for the characteristic speed a persistency in excess of 96 hours would be required before a floating organism would leave the water body segment. Water body Segment II extends approximately 10.6 km (6.6 mi) offshore and stretches along the shore for a distance of 36 km(22.5 mi). The volume of water contained in this segment is 9.6×10^9 m^3 (3.4×10^{11} ft^3). The cross-sectional area normal to the longshore flow has an area of approximately 2.7×10^5 m^2 (2.9×10^6 ft^2) (see Table III-2). In the eastern sector of water body segment II are the Nine Mile Point discharges. Segment II includes 0.59% of the Lake's volume.

4. Conclusions

The topographic, meteorological, and hydrographic characteristics of the southeastern shore of Lake Ontario in the Oswego locality define the near and far field areas of influence of the Oswego Unit 5 thermal discharge and adjacent discharges. The selection of specific adjacent water body segments allow quantitative comparisons of plume parameters and segment parameters for one area at the Oswego site (segment I) and a second area (segment II) including all adjacent thermal discharges.

TABLE III-2

CHARACTERISTICS OF WATER BODY SEGMENTS I AND II

Water Body Segment I

Distance to offshore boundary	3.5 km	2.2 mi
Depth at offshore boundary	30 m	98.4 ft
Distance along shore	13 km	8.1 mi
Surface area	45.5 km^2	17.8 mi^2
Volume within bounds	6.7×10^8 m^3	2.4×10^{10} ft^3
Cross sectional area	5.1×10^4 m^2	5.5×10^5 ft^2

Water Body Segment II

Distance to offshore boundary	10.6 km	6.6 mi
Depth at offshore boundary	~140 m	~450 ft
Distance along shore	36 km	22.5 mi
Surface area	382 km^2	147.5 mi^2
Volume within bounds	9.6×10^9 m^3	3.4×10^{11} ft^3
Cross sectional area	2.7×10^5 m^2	2.9×10^6 ft^2

IV. THERMAL DISCHARGE CHARACTERISTICS

A. PLUME ANALYSIS

1. Introduction

The plume volume, cross-sectional dimensions, and entrained flow are presented in this chapter. These calculated values are used in Chapter VIII in order to assess the effect of the power plant on the lake.

The turbulent and transport processes of a buoyant jet and plume system are not understood sufficiently to permit an exact solution for the desired parameters of the flows. Hence jets and plumes are usually described by theoretical models or well-documented, semi-empirical relationships. In the absence of hydraulic model or field data, a theoretical mathematical modeling scheme is used. These models are based on either dimensional analysis, differential analysis, integral formulation, or finite-element methods. Several of these mathematical modeling techniques for submerged jet discharges have been reported in the literature (Koh and Fan, 1970; Motz and Benedict, 1971; Stefan et al., 1971; Stolzenback and Harleman, 1971; and Anderson et al., 1973). A straight forward technique is the semi-empirical method in which hydraulic model studies or field survey data, if available, are described by empirical relationships. The Oswego Unit 5 plume is herein described by such a semi-empirical model.

Operation of the outfall at the Oswego site results in complex hydrodynamic and thermal interactions with the lake at the discharge site. Limitations of mathematical assessments led to the use of a physical (hydraulic) model to simulate the discharge characteristics (QLM, 1971) for Oswego Unit 5. Similar studies were undertaken to select the proposed Oswego Unit 6 design as well (QLM, 1972). Since the designs are similar, both sets of model results are interpreted as predictions of the prototype discharge plume for Unit 5. Each test series included an undistorted scale model (1:60) and a vertically distorted scale model. The undistorted scale model more accurately describes the plume in the immediate vicinity of the outfall where model boundaries and atmospheric heat transfer do not influence the thermal plume predictions.

The undistorted model was constructed at uniform scale of 1:60 and was operated by Acres American Inc. (1971). The scaling in the model is based on Froude similarity and all results described will be stated in prototype dimensions unless noted. The tests simulated full load (890MWe) gross output at full flow.

2. Selected Hydraulic Model Data

The simulated test conditions for undistorted scale model tests are listed in Table IV-1. The information needed for the analysis described in this section was not reported for the Unit 5 model tests. However, the Unit 6 tests are in many ways very similar to the conditions expected for Unit 5. On the basis of reported results, the hydraulic model test run that best represents the protoytpe behavior of the thermal discharge plume for the selected outfall design is Phase II, model test II-1 of Unit 6 (QLM, 1972). Subsequently this test was selected for the detailed thermal data analysis presented herein. The data obtained from this undistorted model test run provide sufficient information about the expected prototype behavior of the plume to demonstrate its thermal effects on the downstream thermal structure. Figure IV-1 illustrates the isotherm patterns in terms of water surface temperature rise above the lake ambient. The previously reported (QLM, 1972) cross-sectional and longitudinal section isotherms are shown in Figure IV-2.

Figure IV-2 illustrates the limited extent of the immediate discharge area. Although the conditions simulated were adverse to dilution and were "worst case" conditions, it is used throughout this demonstration to describe the immediate discharge zone. The zone is defined by EPA to be that area located within a more than 2°C (3.6°F) ΔT more than 30% of the time. The true discharge zone is seasonal and is expected to be substantially smaller and may at times be orders of magnitude smaller in size.

3. Plume Description

A conceptual model of the plume is developed using empirical and theoretical principles. Downstream from the location of maximum surface temperature the plume is described as a three-dimensional half-jet. Downstream from the location (S_b) of the boil, the surface centerline plume temperature is assumed and supported by observation to decrease exponentially with distance from the location of the maximum temperature at the surface centerline. The constructed plume is also extrapolated back to the jet ports by careful application of the theoretical principles for buoyant jets and available data

4. Surface Temperature versus Distance

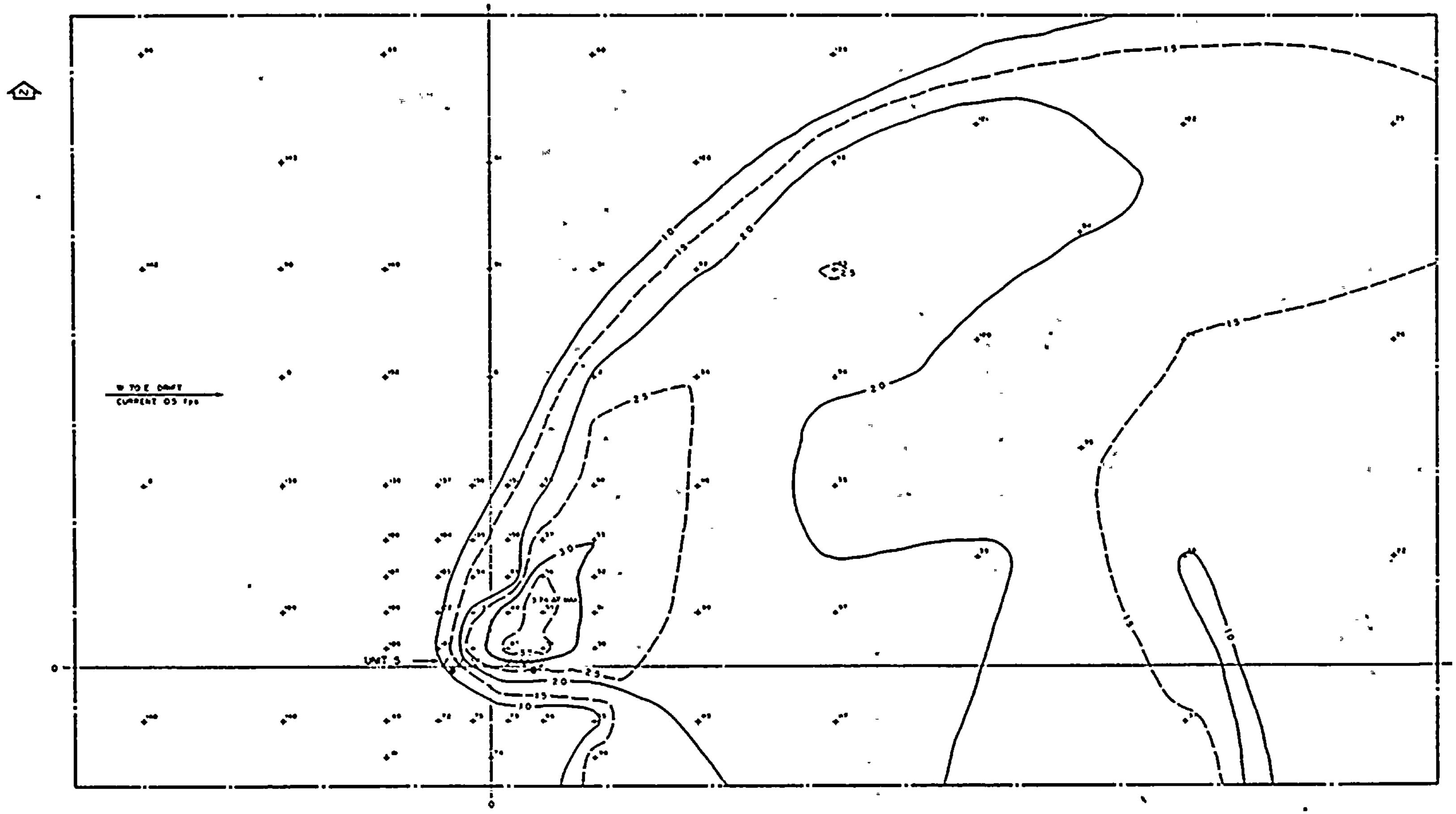
The plume centerline is the line drawn through the locations of maximum surface temperatures. When these surface temperatures at probe locations are plotted against the probe distance from the jet ports on a full logarithmic graph they very nearly form a straight line (Figure IV-3). This indicates that the surface temperature, T*, decreases inversely with some power of the centerline distances. That is,

TABLE IV-1

SELECTED UNDISTORTED MODEL TEST CONDITIONS

(For the Unit 5 Discharge Characteristics)

Model Scale	:	1:60
Ambient Temperature	:	27.3°C (81.2°F)
Diffuser Temperature (above ambient)	:	15.9°C (28.7°F)
Lake Conditions		
Prototype drift current speed	:	15.2 cm sec^{-1} (0.5 fps) from W to E
Prototype water depth	:	8.5 m (28 ft)
Prototype Diffuser Riser Spacing	:	12.2 m (40.0 ft)
Number of Risers	:	6
Prototype Port-diameter	:	0.6 m (2.0 ft)
Diffuser Discharge	:	18.0 m^3 sec^{-1} (635 cfs)
Prototype Jet Velocity at Port	:	5.1 m sec^{-1} (16.8 fps)



TEST CONDITIONS 15

AMBIENT TEMPERATURE [illegible] °F
DIFFUSER TEMPERATURE [illegible] °F ABOVE AMBIENT
LAKE CONDITIONS ○ STILLWATER ■ DRIFT CURRENT W TO E 0.50 fps (PROTO)
WATER DEPTH = 30 FT (PROTO)
INTAKES ■ CLOSED ○ OPEN

DIFFUSER DISCHARGE [illegible] cfs ■ UNIT 5

TIME RECORDS:
DATUM TEMPERATURE MEASUREMENT [illegible] HRS
AMBIENT TEMPERATURE MEASUREMENT [illegible] HRS
HEAT INPUT [illegible] HRS
TEST FINISHED [illegible] HRS

REMARKS:

(20) ISOTHERM PATTERNS ILLUSTRATING THE AVERAGE WATER SURFACE TEMPERATURE (°F) ABOVE LAKE AMBIENT, FOR THE PERIOD 10 TO 16 MINUTES AFTER HEATED WATER HAS BEEN ADDED THROUGH UNIT 5 DIFFUSER

NOTES

CHANNEL NUMBERS OF THE PROBES AT SPECIAL LOCATIONS:
DIFFUSER MANIFOLD CHANNELS 80, 81, 82
AMBIENT TEMPERATURE CHANNELS 140, 8, 142, 66

UNDISTORTED MODEL, 1:60 SCALE
PROTOTYPE SCALE IN FEET
0 120 240 360 480
0 2 4 6 8
MODEL SCALE IN FEET

ACRES
QUIRK, LAWLER & MATUSKY ENGINEERS
NIAGARA MOHAWK POWER CORPORATION
HYDRAULIC MODEL STUDY OF THERMAL DISCHARGE

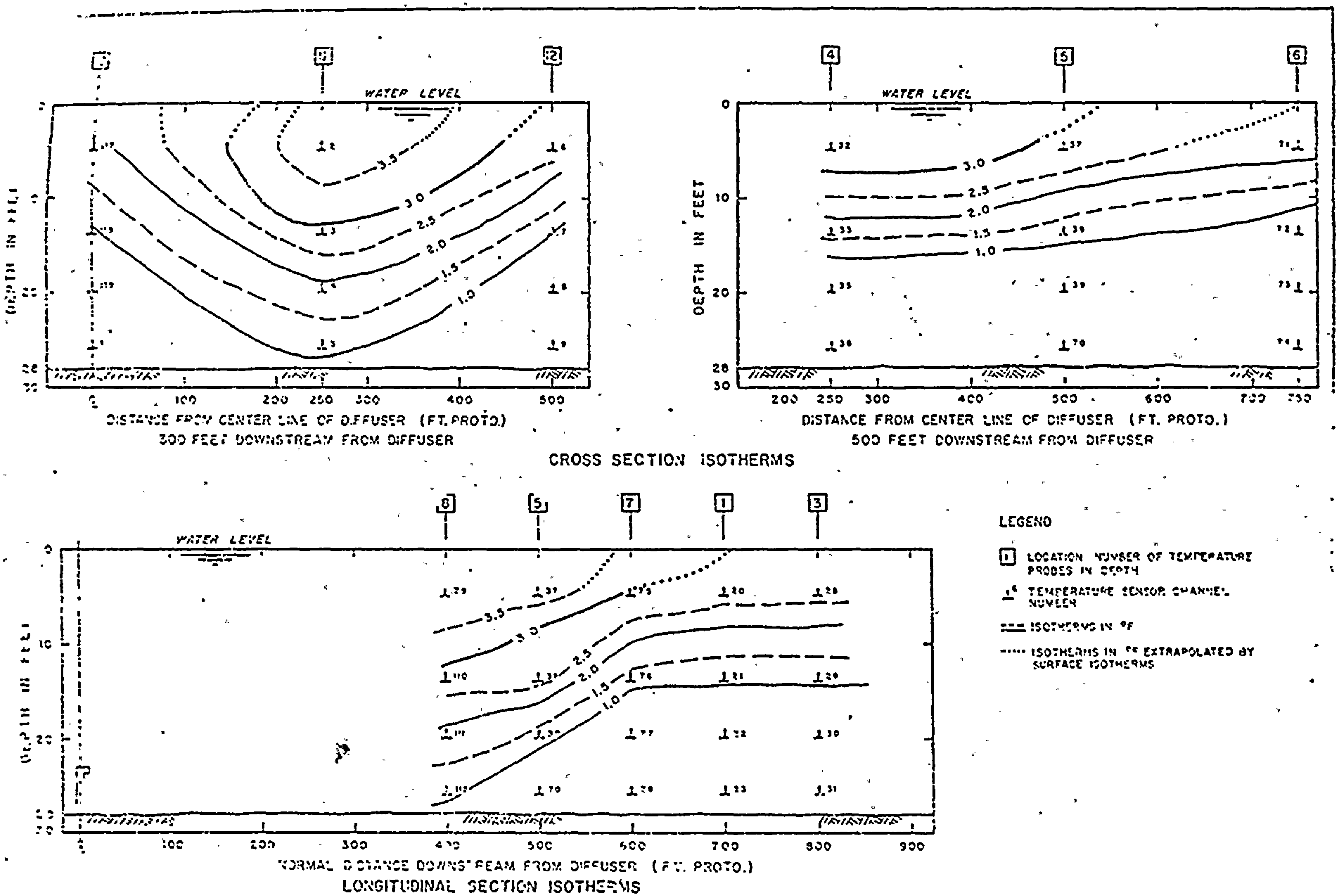
OSWEGO UNIT 5
1:60 SCALE MODEL
TEST 15 (10 TO 16 MIN AFTER HEAT INPUT)
WATER SURFACE TEMPERATURE

ACRES AMERICAN INCORPORATED
JUNE 1972
PLATE 17

FIGURE IV-1

FIGURE IV-2

CROSS SECTION AND LONGITUDINAL SECTION ISOTHERMS



$$T^*(s) \quad \frac{1}{s^a} \qquad \begin{matrix} a > o \\ s > s_b \end{matrix} \qquad \text{(IV-1)}$$

The centerline surface temperature for any near-field location can be determined from Figure IV-3.

5. Isothermal Areas In A Vertical Cross-section

Wherever a probe is located at or near the plume centerline, it is possible to construct a vertical cross-section normal to the centerline from the vertical temperature variation for the probe, and the horizontal surface temperature distribution provided in Figure IV-1.

It has been shown by many investigators that a Gaussian distribution of temperature is a good approximation for submerged and surface jets. Therefore it can be assumed that the temperature in this cross-section decreases exponentially with horizontal distance, r, and vertical instances, z, from the centerline. This temperature, T(s,r,z) is described by

$$T(s,r,z) = T^* (s) \text{ Exp } - \left[\left(\frac{z^2}{B_z} + \frac{r^2}{B_r} \right) \right] \qquad \text{(IV-2)}$$

where B_z and B_r are normalizing parameters which can be graphically determined. If B_r is assumed to be different for both the left and right side of the plume cross-section, the observed plume assymetry is also accounted for.

Figure IV-4 presents the variation of plume area with distance from the port. It can be seen that the isotherm areas grow to a maximum near the discharge (less than 152 m, 500 ft), rise toward the surface, and spread horizontally with increasing distance from the discharge diffuser. The location and maximum area parameters are summarized in Table IV-2.

6. Plume Volumes

The calculation of isothermal areas was described in the previous section, and an interpolated function of area versus distance is illustrated in Figure IV-4. Integration of this function provides estimates of isothermal volumes. A graphical integration was done according to the following expression:

$$V \sum_{s=0}^{S_c} \text{Area} \times s \qquad \text{(IV-3)}$$

SURFACE TEMPERATURE VS DISTANCE ALONG PLUME CENTERLINE

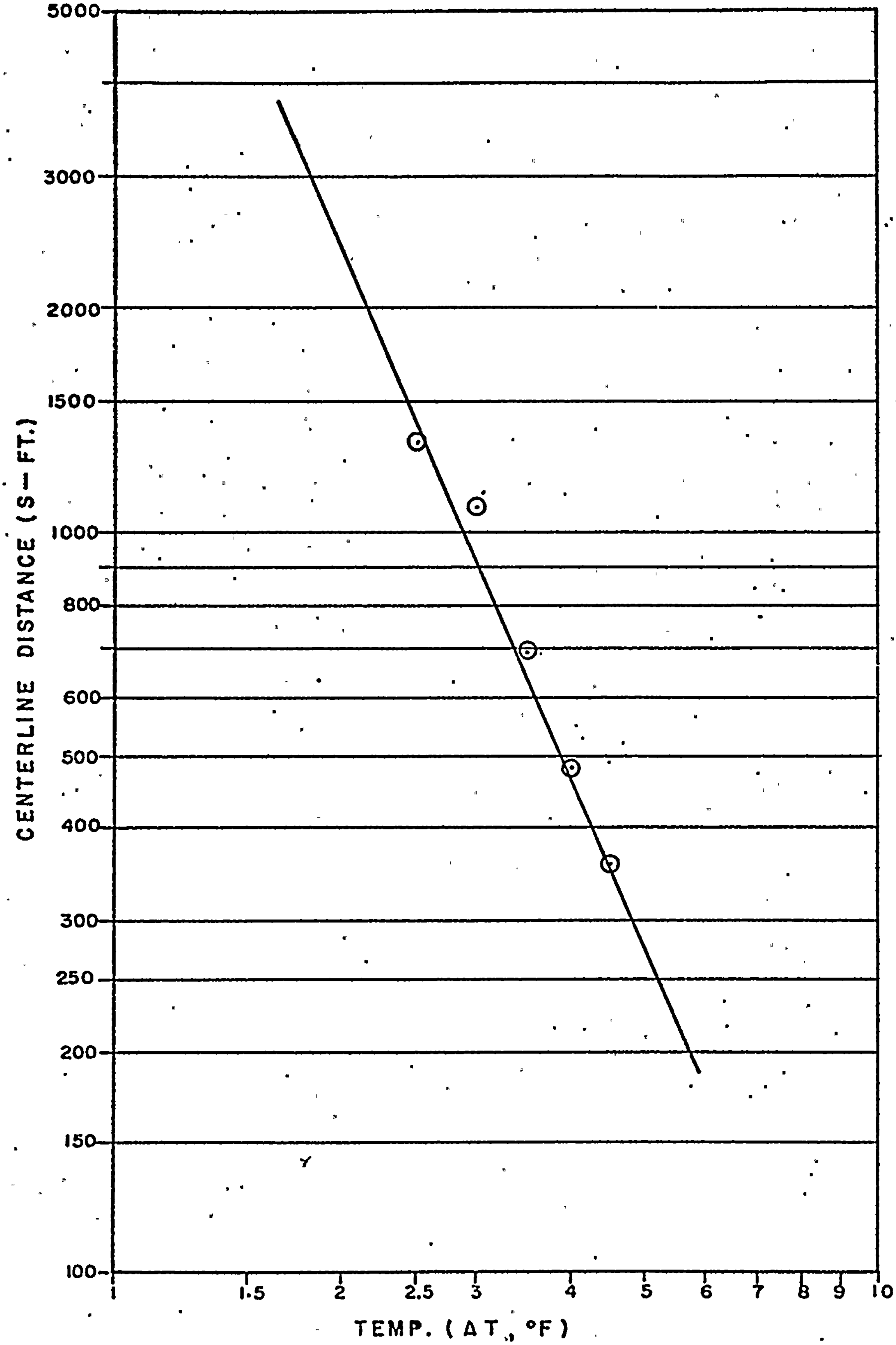


TABLE IV-2

Maximum Cross-sectional Area within an Isothermal Volume and location from the diffuser ports

Isotherm, ΔT		Area, Amax		Centerline dist., S		Average Velocity $\bar{V}$	
°C	°F	m^2	ft^2	m	ft	m/sec	ft/sec
2.50	4.5	27.9	300	83.8	275	0.33	1.07
2.22	4.0	176.5	1900	97.5	320	0.30	0.97
1.94	3.5	325.2	3500	109.7	360	0.27	0.87
1.67	3.0	529.5	5700	121.9	400	0.23	0.76
1.39	2.5	780.4	8400	134.1	440	0.20	0.66
1.11	2.0	1068.4	11500	149.4	490	0.17	0.55
0.83	1.5	1495.7	16100	167.6	550	0.13	0.44
0.56	1.0	2173.9	23400	176.8	580	0.10	0.34

AREA WITHIN AN ISOTHERM AT A VERTICAL CROSS SECTION
NORMAL TO THE PLUME CENTERLINE VS. CENTERLINE DISTANCE

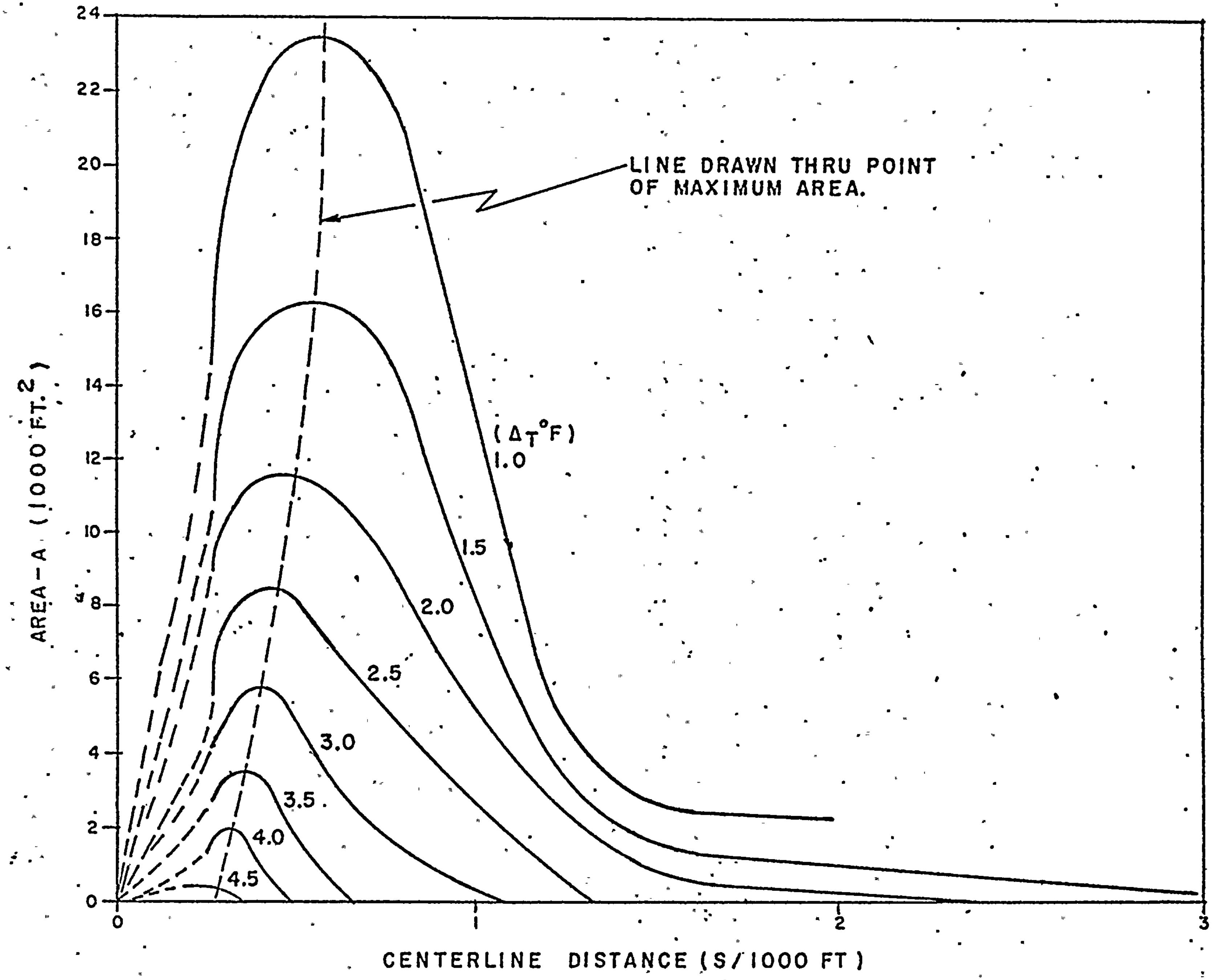


FIGURE IV-4

where S_c is the downstream distance to the location where the chosen isotherm closes at the surface. The estimated volumes are presented in Table IV-3. The use of these volume estimates to assess power plant effects is described in Chapter VIII.

B. ESTIMATION OF ENTRAINED FLOW

The purpose of this section is to provide estimates of lake water entrained into the discharge plume, specifically the entrainment into each isotherm. From the earlier description of plume temperature; a dilution can be calculated for each location in the plume from the following definition:

$$D_T(s,r,z) \equiv \frac{\text{Source Temperature}}{\text{Field Temperature}} \equiv \frac{\Delta To}{\Delta T\ (s,r,z)} \qquad \text{(IV-4)}$$

where source temperature is temperature rise at the diffuser. If the dilution of velocity is related to the dilution of temperature, a field of velocity can be derived. A variety of expressions are available to describe this relationship, but one that is in common usage is,

$$D_H(s,r,z) \equiv \frac{Uo}{U} \equiv \left[D_T\ (s,r,z)\right]^b \qquad \text{(IV-5)}$$

If b = 1, the temperature and velocity are diluted equally. However, usually b>1, as evidenced by plume deflection in an ambient current, until the plume no longer shows the effect of discharge momentum yet there remain noticeable temperature elevations. This is explained by the realization that the discharge momentum has gone to increase the level of turbulent motion in the plume, while the decay of heat is primarily a result of exchange to the atmosphere; that is, the decay of heat and momentum are distinctly different processes.

Although measurements of velocity were made at select probe locations in the model, they are not of sufficient resolution to provide the necessary flow information. Accordingly, a method was developed that relies on the above relationship for dilutions and the principle of heat conservation.

In the near field, there is little loss of heat to the atmosphere. Therefore, heat should be conserved within the plume. The expression that describes this conservation is,

$$H = H(s) = \int_{r=\infty}^{r=\infty} \int_{z=o}^{z=o} u(s,r,z)\rho C\ T(s,r,z)\ dr\ dz \qquad \text{(IV-6)}$$

TABLE IV-3

Exclusion Zone Volumes of the Discharge Plume

Isotherm, °C	ΔT °F	Volume, V_T m^3	ft^3
2.50	4.5	0.0270×10^5	0.9525×10^5
2.22	4.0	0.1158×10^5	4.0895×10^5
1.94	3.5	0.3148×10^5	11.1182×10^5
1.67	3.0	0.7532×10^5	26.5974×10^5
1.39	2.5	1.5267×10^5	53.9137×10^5
1.11	2.0	2.7390×10^5	96.7252×10^5
0.83	1.5	4.2249×10^5	149.2013×10^5

where u is the field velocity, P is the density of the water, C_p is the coefficient of specific heat for water, and T is the field temperature. H is the total heat discharged from the plant. In physical terms, the above expression says that the flux of heat through any cross-section is equal to the heat released by the power plant. Substitution of equation IV-4 and IV-5 into equation IV-6 and rearranging terms yields the following expression:

$$\frac{H_o}{\rho C_p} = \int_{r=\infty}^{r=\infty} \int_{z=o}^{z=-\infty} u_o \left(\frac{\Delta T}{\Delta T_o}\right)^{b+1} dr \quad dz \qquad \text{(IV-7)}$$

where b can be solved for by a trial-and-error procedure.

In practice, it is not possible to integrate numerically to infinity; therefore, some compromise was made. Since heat flows out of the plume through the coolest isotherm, the integration was carried out to the 0.3°C (0.5°F) isotherm at the section nearest the port. The value of b that approximates the heat conservation for the first section for the chosen test run is b = 1.5. The velocity field and the field of flow can be calculated from the field of diluted temperature using b=1.5.

The results of these calculations are presented in Figure IV-5, in which the variation of plume flow within an isotherm as a function of distance from the source is illustrated. The variation of velocity as a function of distance is graphically illustrated in Figure IV-6. The maximum flow is the total entrained flow plus the discharge flow. Downstream from this location the net advection is outward through the isotherm and is not considered entrainment. Table IV-4 presents the maximum flow and entrained flow within each 0.3°C (0.5°F) isotherm. The use of the estimated entrained flow to assess power plant effect is described in Chapter VIII.

C. SEASONAL PATTERNS OF THE THERMAL PLUME

Winter ambient water temperatures were not modeled in the hydraulic study of Oswego Unit 5. However, the model simulation of the winter plume for the Nine Mile Point Nuclear Station Units 1 and 2 (QLM,1974c) at a site approximately seven miles east, within the same climatic area, provides a good qualitative description of the winter plume conditions that can be expected at Oswego. This can be compared with the Oswego model data and analysis of the warmer ambient temperature conditions described in an earlier section.

FLOW THRU AN ISOTHERM VS. CENTERLINE DISTANCE

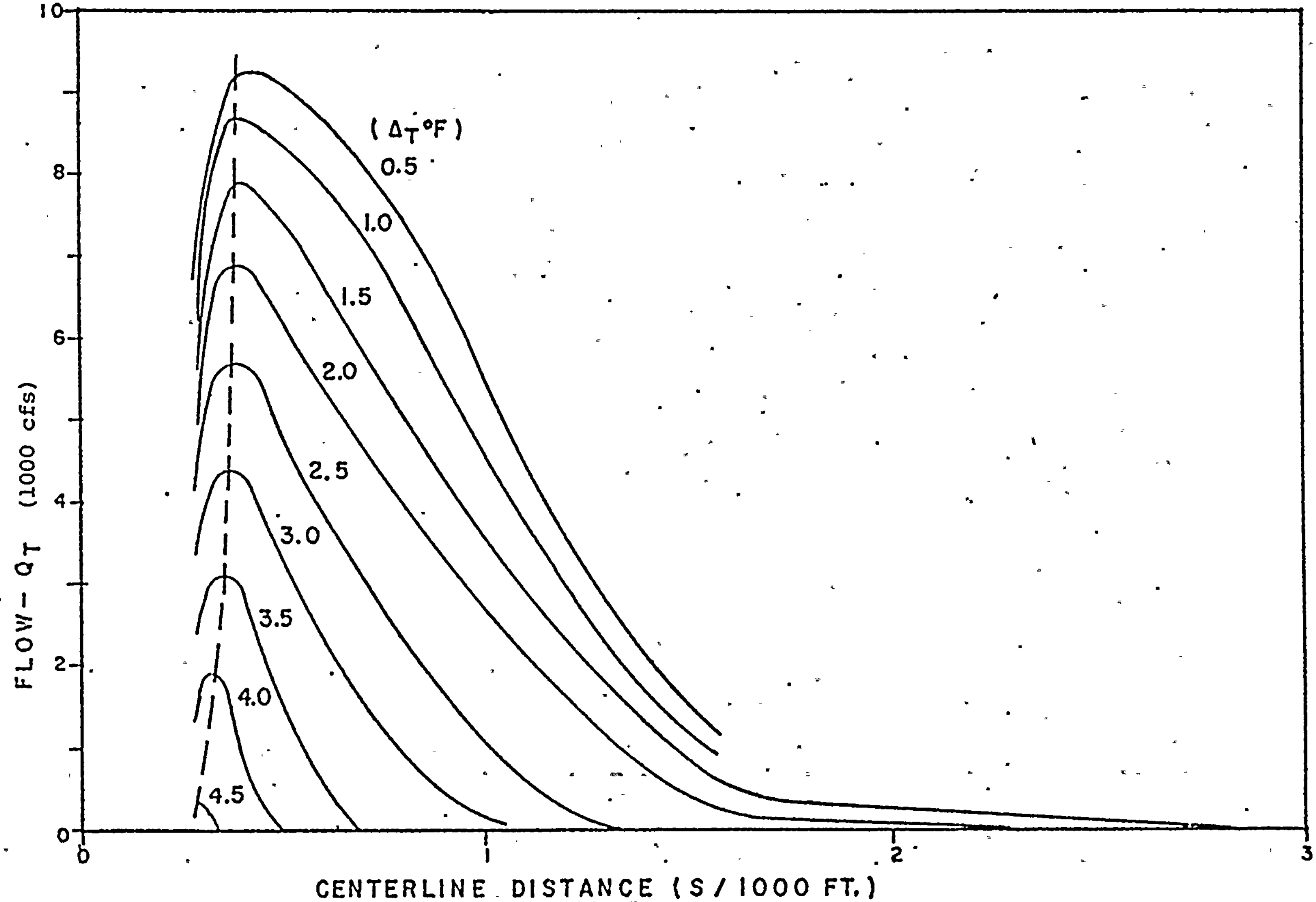


FIGURE IX-5

AVERAGE VELOCITY WITHIN AN ISOTHERM VS. CENTERLINE DISTANCE

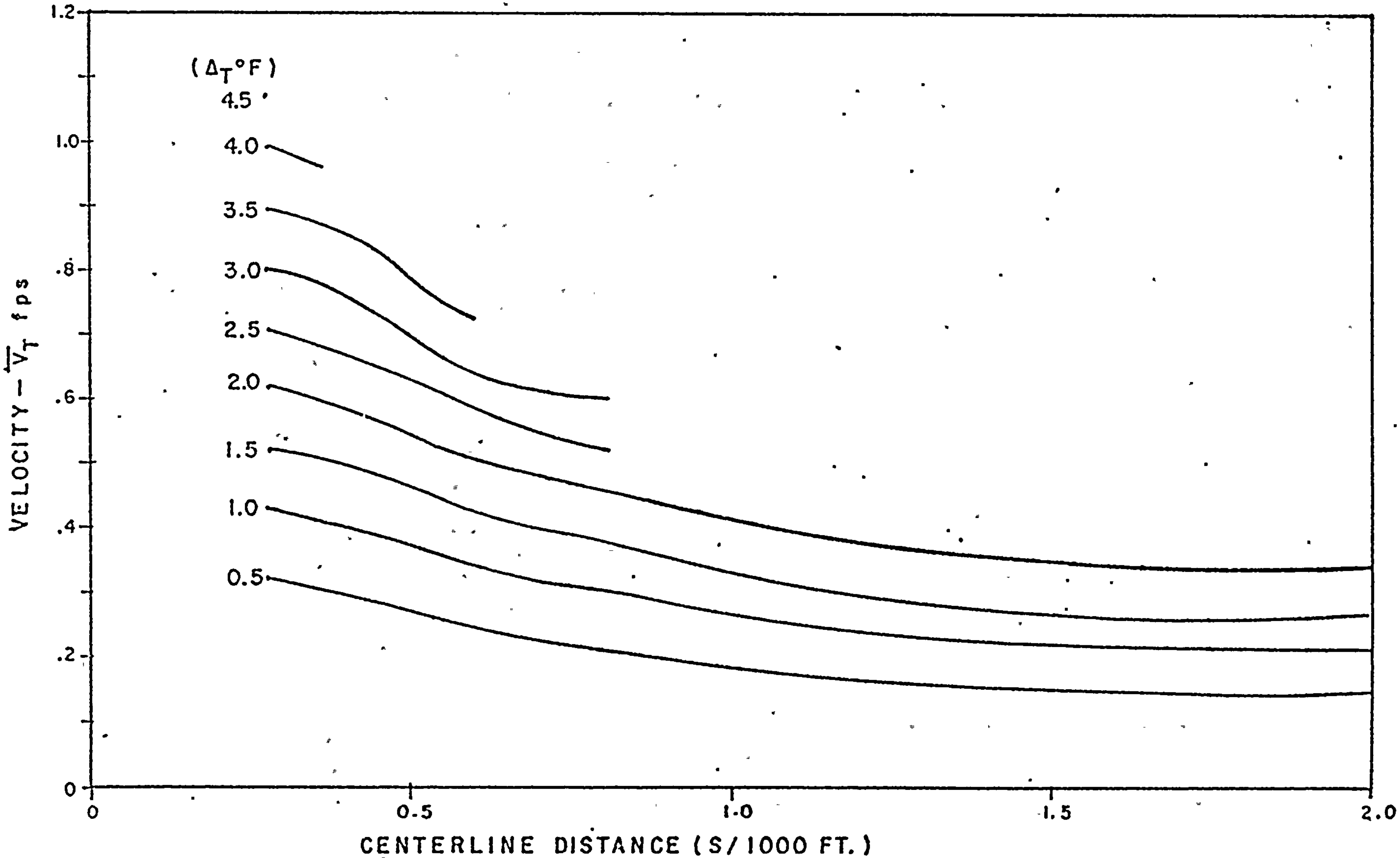


FIGURE IV-6

TABLE IV-4

Maximum Heated Water Flow Within an Isotherm

Isotherms, ΔT °C	°F	Flow, Q_T m^3/sec	ft^3/sec
2.50	4.5	9.06	320
2.22	4.0	53.80	1900
1.94	3.5	86.22	3045
1.67	3.0	124.59	4400
1.39	2.5	161.41	5700
1.11	2.0	192.55	6800
0.83	1.5	223.70	7900
0.56	1.0	252.02	8700
0.28	0.5	260.52	9200

The various test conditions reported by QLM (1974c) include a range of ambient temperatures from 1.5° to 23.7°C (34.7°F to 74.7°F), and a range of ambient currents from 0.5 fps from east to west to 0.5 fps from west to east.

The tests indicate that the effluent dilution of the plumes increases with increasing ambient temperature. At low ambient temperatures, the plume is very compact, with rapid temperature decreases along the plume centerline, as shown in Figure IV-7. The plume temperatures for summer conditions decrease less rapidly than for the colder conditions. The plume also spreads further offshore at the surface and lifts off the bottom more quickly in the summer.

The three-dimensional shape of the winter plume is distinct from the summer shape in that the near neutral buoyancy of the winter plume results in a uniform effluent distribution with depth. At warmer ambient temperatures, the plume takes the shape of an inverted pyramid: a very small plume occurring at the bottom with gradually increasing plume areas towards the water surface. Also, a large diffused plume occurs at the surface. While the winter plume is equal in area and temperature from surface to bottom, the summer plume is larger and cooler at the surface than at the bottom. A comparison of the typical depth profiles of the plume is illustrated in Figure IV-8.

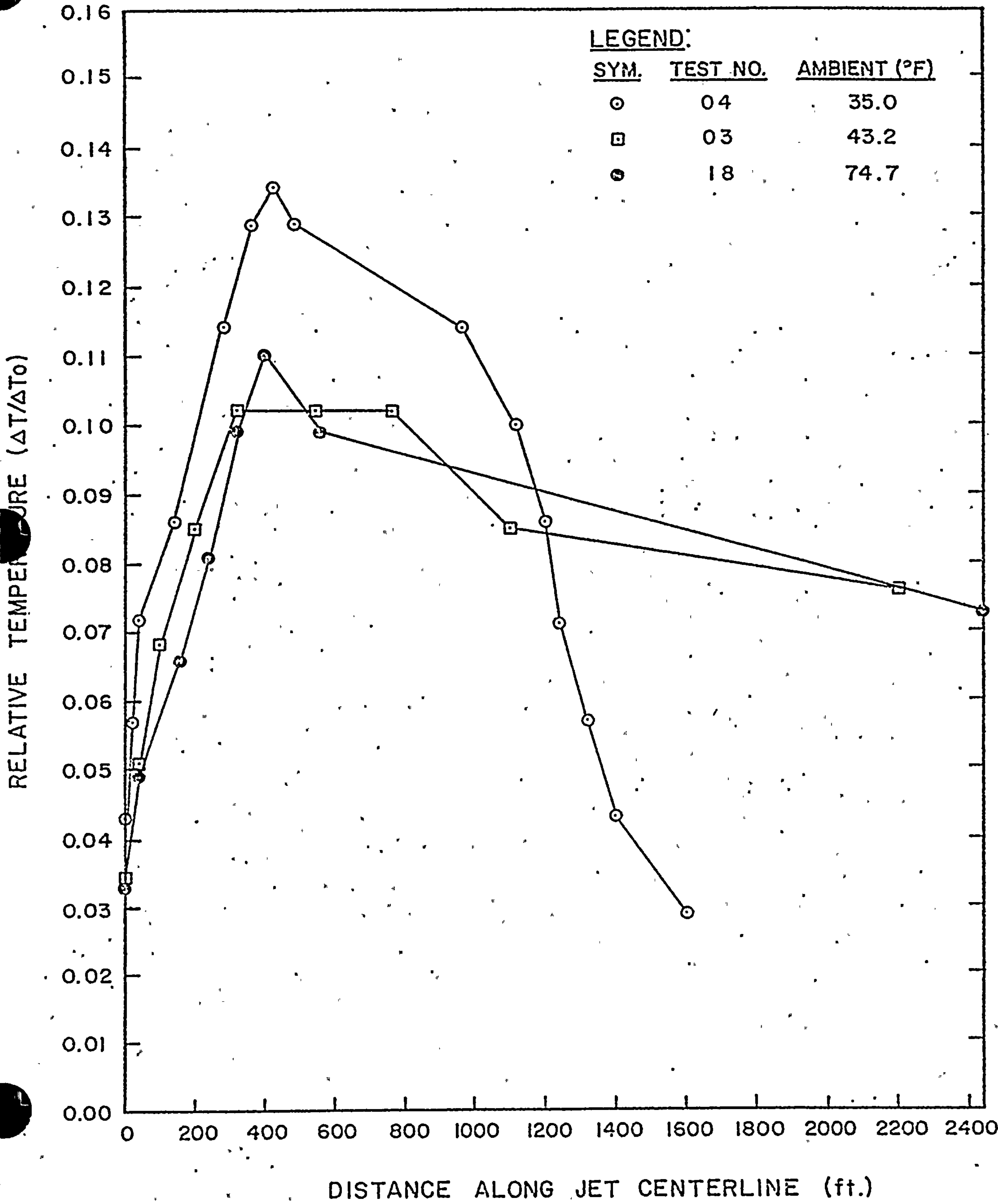
Model tests were not conducted for the Oswego Unit 5 thermal plume at winter ambient temperatures, but the results described above document that the discharge zone for Oswego Unit 5 will be confined to the immediate vicinity of the diffuser in all seasons.

The bottom heating which may result from the discharge will occur mainly in winter when ambient temperatures fall below 4°C (39.2°F), the temperature of maximum water density. During the coldest period in February and March, when ambient is minimum, bottom temperatures of 2°C (36°F) may extend 427 m (1400 ft) from the diffuser. The area so impacted however is only about 0.3 km^2 and the predicted plume does not reach the shoreline. The area represents only 0.6% of the adjacent water body segment I.

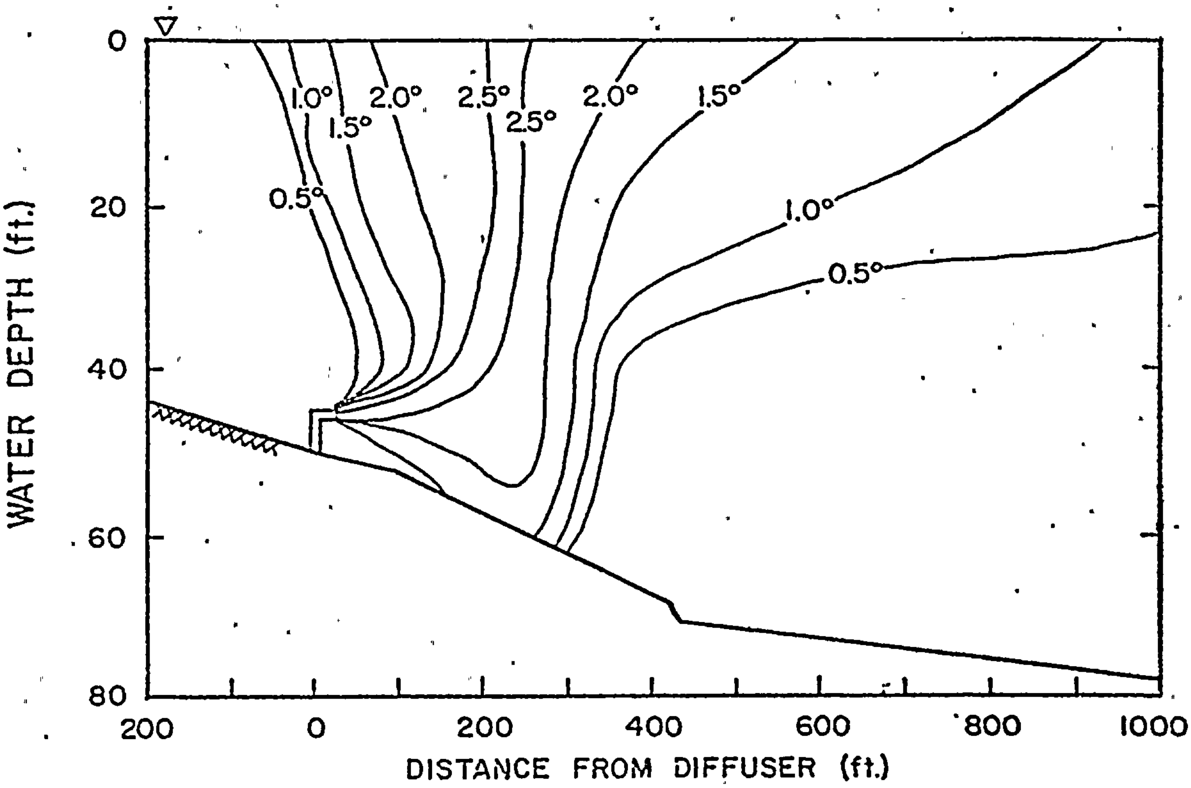
D. SUMMARY OF THE PLUME PARAMETERS

The engineering evaluations in this chapter have led to the delineation of maximum potential impact zones and flows as functions of the temperature rise during full capacity operation of the power plant. Assuming that the effluent dilution characteristics of the plume remain approximately the same, as the discharge temperature rise decreases with decreasing plant load, the plume parameters for the average seasonal loads can be defined from those computed for the full capacity operation.

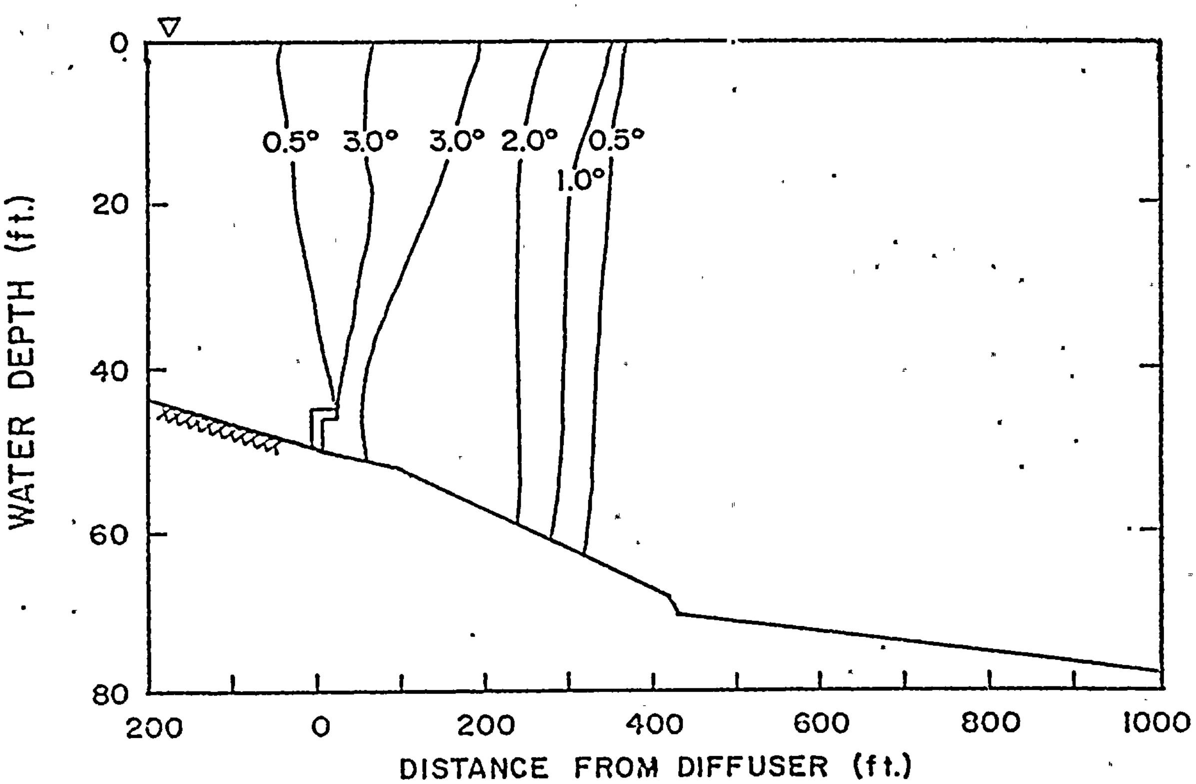
RELATIVE TEMPERATURE VS. DISTANCE
CURRENT: EAST TO WEST (0.5 fps)



PLUME PROFILES



A) BUOYANT PLUME (TEST 14, 0.5 fps WEST to EAST)



B) NON-BUOYANT PLUME (TEST 05, 0.5 fps WEST to EAST)

For a given seasonal mean load, the dilutions are calculated for the various isotherms. The equivalent isotherms, at full capacity operation are then obtained, based on equal dilutions, and the plume parameters estimated from the full capacity tables and graphs. A summary of these parameters is given in Table IV-5. Values reported for the equivalent temperatures that are higher than the maximum plume temperature rise of 4.64 °F (2.58°C) are based on the extropolation of the maximum flow rates to higher temperature rises nearer the outfall.

TABLE IV-5

SUMMARY OF PLUME PARAMETERS FOR
MAXIMUM AND NORMAL AVERAGE PLANT LOAD FACTORS

	UNITS	OPERATION AT FULL CAPACITY (MAX)			SUMMER MEAN LOAD			FALL MEAN LOAD			WINTER MEAN LOAD			SPRING MEAN L(		
OPERATION CAPACITY	%	Full (105)			53.4			70.2			48.7			30.0		
DISCHARGE TEMPERATURE RISE	°F	28.6			16.4			20.0			15.7			10.8		
	°C	15.9			9.1			11.1			8.7			6.0		
		ISOTHERMS			ISOTHERMS			ISOTHERMS			ISOTHERMS			ISOTHERMS		
	°F	1.8	3.6	5.4	1.8	3.6	5.4	1.8	3.6	5.4	1.8	3.6	5.4	1.8	3.6	5
	°C	1.0	2.0	3.0	1.0	2.0	3.0	1.0	2.0	3.0	1.0	2.0	3.0	1.0	2.0	3
FULL CAPACITY* EQUIVALENT	°F	1.8	3.6	5.4	3.14	6.28	9.42	2.57	5.15	7.72	3.28	6.56	9.84	4.77	9.53	14
	°C	1.0	2.0	3.0	1.74	3.49	5.23	1.43	2.86	4.29	1.82	3.64	5.47	2.65	5.30	7

Example: At summer mean load the 2°C ΔT isotherm occupies the same area and volume and entrains the same flow as the 3.49°C isotherm would at capacity operation, as determined from the hydraulic model study.

*Based on equal dilutions

V. BASELINE STUDIES AND COMMUNITY COMPOSITION

A. INTRODUCTION

In order to asess the effects of an electric generating station on the aquatic ecosystem of a water body, the abundance, species composition, and distribution of its biota prior to power plant operation must be delineated. This chapter will provide such baseline preoperational information for the Oswego Steam Station, based on studies at Oswego site and other plants in Lake Ontario. The major biological groups present in this site vicinity will be considered, along with the factors which have been shown to effect these aquatic populations.

Initial field investigations were conducted during the spring, summer, and fall of 1969-1970 by the Lake Ontario Environmental Laboratory (LOTEL) under contract to Quirk, Lawler and Matusky Engineers (QLM, 1971); these studies were later expanded during 1972 (QLM, 1972), 1973 (LMS,1974) and 1974.

Prior to 1971, ecological investigations were conducted by Dr. J. Storr in the vicinity of the Nine Mile Point Nuclear Station Unit 1 under contract to the Niagara Mohawk Power Corporation (Storr, 1973). Storr collected data concerning the basic current flow patterns, and the plankton, benthos, and fish populations observed in the area from 1963 to the present. LMS conducted ecological investigations of the aquatic ecosystem in the vicinity of the Nine Mile Point Nuclear Station during 1972, 1973, and 1974 (QLM, 1974a; LMS, 1975 in preparation). Because the two generating stations at Oswego and Nine Mile Point are in close proximity (within approximately 12.8 km, 8 mi.), ecological data from one site may be utilized to evaluate ecological conditions at the other location.

The programs conducted by LMS (QLM, 1972; LMS, 1974) at the Oswego Steam Station consisted of surveys of plankton (phytoplankton, zooplankton, and ichthyoplankton), benthos, and fish populations during the spring through fall periods at various depths and transect locations. Impingement and entrainment were also monitored at the existing Oswego station. Water quality was investigated by LMS in the vicinity of the Oswego Steam Station (QLM, 1971, 1972; LMS, 1974), including monthly determinations of inorganic nutrients, heavy metals, dissolved oxygen (DO), temperature, pH, and BOD concentrations. Each trophic level of the community within the vicinity of Oswego Steam Station is discussed below.

This chapter summarizes the essential characteristics of the biological community found in the Oswego area. Substantiation of the facts and conclusions presented is found in the previously submitted documentation of the lake surveys through 1973.

B. PHYTOPLANKTON

The phytoplankton stocks in Lake Ontario have been studied by a number of investigators, including Ogawa (1964), Davis (1966), and QLM (1972), (LMS 1974, 1975 in preparation). The species previously identified by these authors encompass all phytoplanktonic groups, notably diatoms, green algae, blue-green algae, and flagellates.

Several investigators have identified the seasonal patterns of phytoplankton occurrence in Lake Ontario (Davis, 1966; Nalewajko, 1966, 1967; Munawar and Nauwerck, 1971; QLM, 1972,1974a). The seasonal patterns are correlated closely with natural changes in two physical conditions (water temperature and light intensity) and with the supply of dissolved inorganic nutrients. Although there is some phytoplankton growth throughout the year, the annual cycle is usually characterized by two periods of rapid and unusually intense phytoplankton growth, termed "pulses" or "blooms." One bloom occurs during the spring and is dominated by diatoms; the other bloom occurs during the fall and is usually dominated by blue-green algae.

The seasonal patterns of phytoplankton observed in the vicinity of the Oswego Steam Station reflect seasonal patterns previously reported in Lake Ontario. The diatom community during the spring was composed principally of Asterionella, Fragilaria, Melosira, and Stephanodiscus (LMS,1974). Reinwand (1969) found that Asterionella, Fragilaria and Tabellaria were major genera of diatoms in Lake Ontario. QLM (1972) identified Asterionella, Fragilaria and Melosira as the major genera of diatoms in the Oswego area.

Munawar and Nauwerck (1971) reported that green algae tended to be the dominant component of the phytoplankton in Lake Ontario during late summer and that blue-green algae were dominant during the fall bloom. LMS (1974) findings substantiate these conclusions.

OLM (1974a) investigated phytoplankton abundance at individual sites to define possible "bloom" proportions of algae. Whipple et al. (1948) suggested that individual cell counts of algae exceeding 5×10^5 cells/l constituted bloom conditions, while densities greater than 3×10^6 cells/l indicated the existence of a troublesome concentration of algae. Utilizing Whipple's density definition, it is noted that only blue-green algae ever reached bloom but not troublesome proportions (7.4×10^5 cells/l on 13 August at OSWW-30 ft) (LMS, 1974). The alga responsible for this high abundance was Microcystis aeruginosa which was present at 5.6×10^5 cells/l. Although blue-green algae were present at a concentration of 5×10^5 cells/l at OSWP-40 ft on 25 October, no individual species was present in bloom proportions.

The phtyoplankton species in the vicinity of Oswego conform closely to the inventories of species recorded for shoal waters in Lake Ontario. The taxonomy of the Oswego phytoplankton reflects the same species

shifts observed in other parts of the lake over the past 50 years. The taxonomy, distribution and abundance of phytoplankters at the Oswego site are essentially the same as has been determined for the lake as a whole.

C. ZOOPLANKTON

1. Microzooplankton

The second category of organisms is the microzooplankton, the members of which are an integral part of the aquatic community in the vicinity of Oswego Steam Station. To facilitate a division of zooplanktonic populations on the basis of size, microzooplankton may be defined as those organisms retained by a 76 μ mesh plankton net. Many of the larger and usually faster swimming organisms (macrozooplankton and ichthyoplankton) are not captured in a 76 μ net with the 0.5 m mouth diameter as was used by LMS (1974).

The microzooplankton fraction of the total zooplankton community in the vicinity of Oswego Steam Station is composed of four major taxonomic groups: rotifers, cladocerans, copepods and protozoans. Fourteen genera of rotifers and five genera of cladocerans were identified; copepods were identified as adults and nauplii; and two genera and one family of the most commonly occurring protozoans were identified.

Rotifers occurred in a bimodal pattern of seasonal abundance. The first of the two pulses of abundance occurred during July and was followed by a depression in rotifer numbers during August. Rotifer populations increased thereafter to the second peak in late September or late October (LMS, 1974). Rotifer populations decreased between late October and late November.

The seasonal pattern of cladoceran abundance was also bimodal: the first peak occurred during September, and the second peak occurred during October or November. The copepods in the vicinity of Oswego Steam Station followed closely the seasonal patterns and numbers of abundance exhibited by the cladocerans (LMS, 1974).

The seasonal pattern of protozoan abundance was bimodal; only the later portion of the first pulse was apparent during May, the month when the 1973 sampling program began. The depression in protozoan numbers between the two pulses occurred during June and July, depending on the station. The peak of the second pulse in abundance occurred during August and protozoan numbers decreased rapidly after August (LMS, 1974).

The total microzooplankton population showed the combined seasonal trends in abundance of the four groups discussed previously. At most stations,

the result was a bimodal seasonal pattern. The greatest numbers of microzooplankters occurred during July; there were approximately 1.7 x 10^3 microzooplankters/m^3 present at all stations during the month. Abundance throughout the sampling period was over 10^3 microzooplankters/m^3 on most sampling dates during 1973 (LMS, 1974).

Glooschenko et al. (1972) found a bimodal pattern in the seasonal abundance of zooplankton at a station in eastern Lake Ontario. The occurrence of the two peaks of abundance was similar to that observed by QLM studies in the vicinity of the Oswego Steam Station, but the number of organisms found by Glooschenko et. al. was about an order of magnitude less than the number of organisms found in the vicinity of the Oswego Steam Station (see QLM, 1972 and 1974a).

Gachter et al. (1974) found a quadrimodal seasonal pattern of zooplankton biomass in the littoral areas of Lake Ontario; the first two pulses occurred during late February and late April and the last two pulses occurred during the time when pulses were observed by QLM in the waters off the Oswego Steam Station.

2. Macrozooplankton and Ichthyoplankton

Classifications according to size are widely used for distinguishing smaller and larger members of the plankton community. For the purposes of the 1973 survey in the Oswego Steam Station vicinity, the term "macrozooplankton" was defined as those invertebrate zooplankters retained in a 571μ mesh plankton net; "ichthyoplankton" was defined as the vertebrate zooplankters (fish larvae) retained in a 571μ plankton net.

There have been no previous studies of the macrozooplankton *per se* in Lake Ontario. The information obtained by QLM (1972) and LMS (1974) forms the basis of knowledge concerning the abundance and distribution of macrozooplankton in Lake Ontario. However, invertebrate crustaceans of the same species may be found in both the macrozooplankton and microzooplankton due to the wide range of sizes encompassed by the developmental stages of these organisms.

There are few published data on the distribution and abundance of fish larvae in the Oswego area; some information is available (although not specifically related to the Oswego vicinity) concerning the feeding habits of larval fish. Since alewives are the most abundant fish in the study area,the larvae of this fish are the dominant ichthyoplankter, among a total of 12 larval species found (QLM, 1972; LMS, 1974, 1975 in preparation). Although Lake Michigan populations may differ from Lake Ontario populations, Norden's (1968) study of alewife larvae in Lake Michigan will serve to provide background information. Norden found that alewives spawned from June through August and that larvae greater than 5mm in length were most abundant during August, September and October. Stomach content analyses revealed that alewife larvae fed predominantly on copepods and cladocerans 200 to 300μ in cross-section.

Eleven major macrozooplankton groups were identified from collections made in the vicinity of the Oswego Steam Station during 1973 (LMS, 1974). The bulk of the macrozooplankton community was composed of cladocerans, copepods, and amphipods. Nematodes, gastropods, mysids and insect larvae were occasionally found in macrozooplankton samples.

All the samples collected during 1973 were analyzed for total fish larvae; however, only selected samples were chosen for the speciation of larvae. Alewives were by far the most abundant larval species; the other species listed in Table V-1 occurred on few collection dates and in small numbers.

Larval alewives were found from early June through late August in surface samples collected during the daylight hours. The typical seasonal abundance pattern was characterized by a rapid increase from early June through early July and an almost equally rapid decrease from the July maximum through late August. A small second peak of abundance in early August was noted at five of the fifteen stations sampled; a single midsummer peak in larval alewife abundance was found at most stations. The abundance of alewife larvae in night collections made from late June through early August was usually an order of magnitude greater than the abundance of these fish larvae in day collections.

The seasonal patterns of total larval abundance reflected the seasonal patterns of larval alewife abundance at most stations (LMS, 1974). During late October, however, a fall pulse of rainbow smelt larvae was found.

Rainbow smelt, johnny darters, carp and mottled sculpin formed small percentages of the total fish larvae population during the early summer. The larvae of white perch, common shiners, yellow perch, emerald shiners and pumpkinseeds were also represented in samples collected during the early summer. Spottail shiner larvae and unidentified shiner larvae were also collected on at least one sampling date (LMS, 1974).

Most of these larvae were found in samples collected between late June and late August; however, rainbow smelt larvae were collected during mid-May and mottled sculpin larvae and rainbow smelt larvae were found in early November collections.

Since the vast majority of larvae collected were alewives, the trophodynamic importance of other species of fish larvae in the Oswego area seems to be comparatively minor. Rainbow smelt larvae occurred during more sampling efforts (10 of the 15 sampling dates) than any other species; alewives occurred in samples collected on 8 different dates. The occurrence of larval johnny darters and carp paralleled the occurrence of alewife larvae.

TABLE V -1

LARVAL FISH COLLECTED IN THE VICINITY OF THE OSWEGO STEAM STATION 1973

Common Name	Scientific Name
Alewife	*Alosa pseudoharengus*
Johnny Darter	*Etheostoma nigrum*
Carp	*Cyprinus carpio*
Mottled Sculpin	*Cottus bairdi*
White Perch	*Morone americana*
Rainbow Smelt	*Osmerus mordax*
Yellow Perch	*Perca flavescens*
Spottail Shiner	*Notropis hudsonius*
Common Shiner	*Notropis cornutus*
Emerald Shiner	*Notropis atherinoides*
Unidentified Shiner	*Notropis* sp.
Pumpkinseed	*Lepomis gibbosus*

D. BENTHOS

Benthic organisms are those attached to, resting on the bottom, or living in the sediment of a body of water (Odum, 1971). Studies of the benthic community in Lake Ontario show that several organisms exhibit distinct distributional patterns. Brinkhurst (1969) reported that the general distribution in Lake Ontario followed the distribution of benthos in temperate oligotrophic water bodies having some inshore areas supporting eutrophic forms. Historically, benthic studies have been concentrated in the eastern portion of Lake Ontario (Johnson and Matheson, 1968); Johnson and Brinkhurst, 1971 a,b). The entire lake, including some stations in the Oswego area, has been sampled by some investigators (Hiltunen, 1969); other studies have been concentrated entirely in and around Oswego (Judd and Gemmel, 1971; Storr, 1972; QLM, 1972). Judd and Gemmel (1971) observed few organisms in the shore zone; the fauna increased in abundance and diversity with depth.

Benthic sampling conducted by Engel (see QLM, 1971) during 1970 was concentrated in the Oswego River and Oswego Harbor area. Engel reported that oligochaetes were the dominant group collected; other groups, including gastropods, dipterans, and amphipods, were distributed in relation to depth or substrate type. QLM (1972) sampled the benthic community in the lake at the Oswego Steam Station at 10, 20, 30, and 40 ft depths during 1972. A general distribution pattern of decreased abundance and biomass with increasing depth was observed. In the spring collections, high organism concentrations were observed in the shallow water Cladophora growth. Amphipods, dipterans and oligochaetes were dominant in this benthic community.

Sampling in Lake Ontario in the vicinity of the Oswego Steam Station during 1973 was expanded to include a second transect west of the plant. The second transect permitted comparison of the benthic communities at the Oswego plant with zones outside the area which will be influenced by the thermal discharge from the Oswego Steam Station Unit 5 and 6.

The plant transect was directly lakeward from the Oswego Steam Station; the west transect was approximately three miles to the west of the plant. The two shallower water stations at the west transect were mainly bedrock* and rubble,** with a small amount of sand and silt***, at the 20 ft station. The 30 and 40 ft stations at the west transect were mainly rubble with sand and silt.

The 10 and 20 ft stations at OSWP were similar; however, there was less rubble and more sand and silt at OSWP 20 ft site. The substrate at the 30 and 40 ft stations was rubble with a small percentage of sand and silt. The absence of sand and silt from the 10 ft stations is the result of wave action and shore currents.

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* Unbroken solid rock

** Rocks 2 to 64 mm in diameter (Weber, 1973)

*** Particles smaller than 2 mm in diameter (Weber, 1973)

A total of five phyla were represented in benthic collections from the vicinity of the Oswego Steam Station during 1973; 59 genera were identified (LMS, 1974). The majority of the organisms collected represent species associated primarily with the surface of the substrate, i.e., epi-benthic species, such as Gammarus fasciatus. However, several infaunal forms, including members of the class Nemata, were also collected.

Seasonal trends in benthic invertebrate abundance in temperate zones usually follow this pattern; reproduction during the spring; growth through the summer and fall; decreased numbers and activity with the onset of cold water temperature (Ruttner, 1963; Odum, 1971; Fretwell, 1972). This general trend was observed at the Oswego Steam Station transects during 1973.

Segmented worm abundance was found to be different by date and transect. A significantly greater number was collected at OSWP during October and June, which were similar; and both were significantly different from the August abundance. The greater abundance found at the plant transect could be the result of influence from the Oswego River (QLM, 1972), and the smaller numbers in August due to avoidance (burrowing) and formation of protective cocoons (Pennak, 1953; Brinkhurst, 1969).

Arthropoda (except for Acarina) were collected intermittently during the survey. The analysis included all three groups but the results basically reflect the distribution pattern of the aquatic mites. A significantly greater number was collected during August and October than during June as a result of the spring period of reproduction.

The small crustaceans of the order Podocopa are important links in the cycling of energy through the ecosystem. Abundance and biomass exhibited a seasonal cycle. A significantly greater number was collected in June than August, and the August abundance was significantly greater than October abundance (LMS, 1974). Biomass followed the same trend; however, August and October had similar biomass values. Insecta (primarily the order Diptera) did not exhibit any significant differences for date, depth and transect (LMS, 1974).

The benthos in the vicinity of Oswego are similar to populations and associations found in Lake Ontario in general.

E. FISH

Fish communities in the Oswego area of Lake Ontario were sampled regularly from June through November 1973 by trawling, gill netting and seining. All collections were made along two transects extending perpendicularly into the lake from the south shore of Lake Ontario. One transect originated at the Oswego Steam Station (designated OSWP); the other was located about 2 miles west of the station (designated OSWW).

A total of 24,401 fishes of 35 species was collected by the three sampling gears (seines, trawls, gill nets) over the seven months of sampling (Table V-2). Of this total, 81.3% were alewives, 5.6% were spottail shiners, 4.2% were white perch, 2.6% were yellow perch, 1.9% were smallmouth bass and 1% were white suckers. The remaining 3.4% of the total catch was divided among 29 species. Few large piscivores were found in the Oswego area; one coho salmon, one shallow water cisco, four northern pike, and 48 walleyes were collected over the course of the 1973 program (LMS, 1974).

The objective of the 1973 fisheries study was to define the fish populations in the vicinity of the Oswego Steam Generating Station as part of a second year preoperational ecological survey for the operation of Oswego Unit 5.

The data were based upon measurements of parameters of abundance and biomass; assessment was based on comparison of a control station (OSWW) with the area of investigation (OSWP). The dominant fish species in the vicinity of the Oswego Steam Station during 1973 were alewives, spottail shiners, white perch, yellow perch, smallmouth bass and white suckers. All of these fish are commonly found in mesotrophic or eutrophic waters. Twenty-nine other species were also collected.

Samples collected by seining showed the nearshore areas to be relatively unproductive; populations were dominated by alewives, bluegill sunfish and emerald shiners. There were no statistically significant differences in fish abundance or biomass in trawl samples between OSWP and OSWW. At OSWP, more fish were caught at night than during the day. Fish were most abundant at both OSWW and OSWP during the spring and summer.

Alewives were the dominant fish in the offshore waters sampled by trawling; rainbow smelt, emerald shiners, and three-spined sticklebacks were also caught in offshore waters (LMS, 1974). There were no significant differences in fish abundance or biomass, as determined from gill net samples, between the two transects; the 30 ft depth contour was significantly more productive than the 40 ft depth contour. Statistically, significant differences in fish populations between collection dates were due to seasonal patterns of abundance; more fish were collected during the spring and summer months. The fish populations are similar along the entire area from the west transect to Nine Mile Point.

F. <u>SUMMARY</u>

The aquatic community in the vicinity of Oswego as determined by the baseline studies is characteristic of Lake Ontario. Spawning does occur in the vicinity of Oswego, but no species depend on the zone of the discharge plume as a unique spawning or nursery area.

TABLE V -2

INVENTORY OF FISHES COLLECTED FROM THE VICINITY OF OSWEGO STEAM STATION 1973

Scientific Name*	Common Name
Family Petromyzontidae	
Petromyzon marinus	Sea lamprey
Family Lepisosteidae	
Lepisosteus osseus	Longnose gar
Family Anguillidae	
Anguilla rostrata	American eel
Family Clupeidae	
Alosa pseudoharengus	Alewife
Dorosoma cepedianum	Gizzard shad
Family Salmonidae	
Coregonus artedii	Shallow water cisco
Oncorhynchus kisutch	Coho salmon
Family Osmeridae	
Osmerus mordax	Rainbow smelt
Family Esocidae	
Esox lucius	Northern pike
Family Cyprinidae	
Carassius auratus	Goldfish
Couesius plumbeus	Lake chub
Cyprinus carpio	Carp
Notropis cornutus	Common shiner
Notropis hudsonius	Spottail shiner
Notropis atherinoides	Emerald shiner
Family Catostomidae	
Catostomus commersoni	White sucker
Moxostoma macrolepidotum	Shorthead redhorse
Family Ictaluridae	
Ictalurus nebulosus	Brown bullhead
Family Percopsidae	
Percopsis osmiscomaycus	Trout perch

TABLE V -2 Continued

INVENTORY OF FISHES COLLECTED FROM THE VICINITY OF OSWEGO STEAM STATION 1973

Scientific Name*	Common Name
Family Gasterosteidae	
Gasterosteus aculeatus	Threespine stickleback
Family Cottidae	
Cottus bairdi	Mottled sculpin
Family Percichthyidae	
Morone americana	White perch
Morone chrysops	White bass
Morone mississippiensis	Yellow bass
Family Centrarchidae	
Ambloplites rupestris	Rock bass
Lepomis macrochirus	Bluegill
Lepomis gibbosus	Pumpkinseed
Micropterus dolomieui	Smallmouth bass
Pomoxis nigromaculatus	Black crappie
Family Percidae	
Etheostoma nigrum	Johnny darter
Percina caprodes	Logperch
Perca flavescens	Yellow perch
Stizostedion vitreum	Walleye
Family Sciaenidae	
Aplodinotus grunniens	Freshwater drum
Family Amiidae	
Amia calva	Bowfin

*According to, "A List of Common and Scientific Names of Fishes From the United States and Canada, 1970," Amer. Fish Soc., Spec. Publ. No. 6 (3rd Ed.).

VI. SELECTION OF REPRESENTATIVE IMPORTANT SPECIES

A. RATIONALE

Four criteria were used to aid in the selection of representative important species as required for the 316(a) demonstration at the Oswego Steam Station. They are: 1) the recreational and commercial importance of the particular species, 2) the functional or trophic level within the aquatic ecosystem, 3) whether or not the fishes are a nuisance species or are endangered, and 4) an examination of community dominants with respect to biomass or to numerical abundance. This list of species was submitted to EPA Region II on June 30, 1975. EPA tranmitted a formal list to NMPC on August 11, 1975. The species discussed in this chapter includes all species cited on either list.

The sources of information which were used include: (1) published literature regarding the biology of a given species; (2) determinations of importance to the ecosystem based on biological monitoring programs which have been conducted in the Oswego/Nine Mile Point area since 1963; and (3) design features, location, and predicted plumes of the thermal discharge which may result in impact on the distribution and abundance of the selected species.

1. Recreational Fish Species

Among the most abundant recreational fish species observed in vicinity of the Oswego/Nine Mile Point area, based upon lake collections conducted during the biological sampling program, are the smallmouth bass, yellow perch, and white perch.

These species composed 8.7% (2,126) of the catch per unit effort in the 1973 Oswego Steam Station monitoring programs; they support a local sport fishery and serve as an attraction for many anglers, especially during the vacation season. In addition, smallmouth bass spawned in the Oswego area during June and July, 1973 (LMS, 1974), and yellow perch egg masses were found in the vicinity in 1974. Therefore, based upon their recreational value, and because they spawn in the area, these species should be considered representative important fish species for the study site.

In recent years the Province of Ontario and New York State have begun fish stocking programs in Lake Ontario. The New York State fish stocking program includes the stocking of salmon (coho and chinook) and trout (brown, lake, and rainbow). Historically, the salmon stocking program was initiated based upon two factors: (1) the recreational value of salmon and, (2) the abundance of alewives in Lake Ontario.

Because salmon have been reported to feed on alewives, it was anticipated that introduction of salmon into the lake would limit or control the alewife population as well as providing a recreational fishery. During 1974, approximately 400,000 lake trout and 42,000 brown trout were stocked in Lake Ontario; approximately 500,000 coho salmon and nearly 1,000,000

chinook salmon were introduced into 11 streams which flow into Lake Ontario. Trout and salmon represent minimal (<0.1%) numbers in the lake in the vicinity of Nine Mile Point and Oswego, based upon lake and impingement collections by LMS during 1973.

Although the low abundance of these species would seem to preclude them from consideration as representative important species, efforts by New York State to stock these species, as well as their potential recreational value have led to their inclusion in this demonstration.

2. Commercially Important Species

Historically, fish productivity within Lake Ontario has been lower than that of the other Great Lakes. A combination of overfishing and the introduction of competitive fish species (e.g., alewife and rainbow smelt) has contributed to the decline in commercial fish production in Lake Ontario (Christie, 1973). Among the commercially important species in the lake are the rainbow smelt, white perch, and yellow perch. Although the alewife is commercially exploited in Lake Michigan, this species is presently not considered a commercially important species in Lake Ontario.

The alewife and rainbow smelt are the most abundant species in the vicinity of Oswego and Nine Mile Point, constituting more than 75% of the lake collections and over 90% of fish impingement during 1973. In both instances, the alewife dominated the fish community. Fish collections in the vicinity of the Oswego Steam Station and Nine Mile Point indicate that white perch constituted 4.2% and 7.3%, respectively, of the lake population at these locations. In addition, analysis of white perch population dynamics (e.g., coefficient of maturity) indicates that this species spawned within the Nine Mile Point vicinity during 1973. White perch will be considered representative due to their abundance and spawning near Oswego. Because of their abundance, the alewife and rainbow smelt also have been chosen for this demonstration.

3. Species Important to the Forage Base

The recreational and sport fish species of Lake Ontario prey upon several smaller fish species including alewife, johnny darter, emerald shiner, threespine stickleback, and spottail shiner (Scott and Crossman,1973). The alewife has been selected previously due to its numerical abundance, its potential commercial value, and as a forage base for the stocked salmon population. The threespine stickleback has shown fluctuations in abundance from year to year and site to site which may be related to their schooling and spawning habits. Male sticklebacks establish and defend territories during the breeding season. They require a bottom with vegetation in order to build a nest, and since the area of such bottom is relatively small in the vicinity of Oswego Steam Station, only a portion of the male population becomes established or fixed to

a territory. The remaining males and non-reproducing females move about in groups and schools. It is predominantly members of this latter group which are increasing in abundance and being impinged, at least during the spawning season. At other times of the year, most individuals of the species form schools and are available to impingement. Greater impingement of these nonreproducing individuals is also apparent (LMS, 1974). The threespine stickleback are thus evaluated as a representative species due to their abundance in the collections and their resident spawning activities.

The dominance of the spottail shiner over other forage species in lake collections, their distribution over wider areas and greater depths, their continual presence on virtually all collection dates in the lake and plant, and their presence in stomachs of larger fish suggest that this species is an important representative of the community.

Gammarus fasciatus is an amphipod (invertebrate) chosen by EPA as a representative species because of its importance as a forage base for the young and adults of many species of fish.

4. Threatened and Endangered Species

Lists of threatened and endangered species are published by the U.S. Department of the Interior. A review of these publications, current issues of the Federal Register and technical literature indicates that the following species from the Great Lakes or Lake Ontario in particular are considered threatened endangered, or rare:

1. Lake sturgeon (Acipenser fulvescens)
2. Blue pike (Stizostedion vitreum glaucum)
3. Kiyi (Coregonus kiyi)
4. Blackfin cisco (Coregonus nigripinnis prognathus)
5. Shortnose cisco (Coregonus reighardi)

None of these fish have been collected in the vicinity of either Nine Mile Point or Oswego in the course of the extensive biological monitoring programs of the last three years.

The guidance manual suggests that descriptions of these species be provided and this is done in the following paragraphs.

Lake Sturgeon (Acipenser fulvescens)

Once the lake sturgeon was quite abundant in Lake Ontario; in fact, in 1855 a commercial processing plant was established at Sandusky, Ohio. Since then the lake sturgeon, especially in Lake Erie, has been almost eliminated. A detailed description of the decline of the Great Lakes sturgeon fishery can be found in Harkness and Dymond (1961).

No lake sturgeons were collected in 1973 or 1974 in either the general ecological surveys or impingement collections.

Blue Walleye (Stizostedion vitreum glaucum) (also known as Blue Pike)

This species consisted of two subspecies, the yellow walleye, Stizostedion v. vitreum, and the blue walleye, S v. glaucum. The blue walleye was placed on the Rare and Endangered list (McAllister, 1970) as rare or perhaps extinct. Scott and Crossman (1973) conclude that it has totally dissappeared from Lakes Erie and Ontario.

None were collected in 1973 and 1974 by sampling programs near the site.

Blackfin Cisco (Coregonus nigripinnis prognathus)

The blackfin cisco once ranged throughout all the Great Lakes except Lake Erie, but now has disappeared from Lakes Ontario and Michigan. There were none collected in 1973 or 1974 by LMS.

Kiyi (Coregonus kiyi)

The kiyi was indigenous to the Great Lakes basin and was limited in distribution to the deeper waters of lakes Ontario, Huron, Michigan and Superior. It has virtually disappeared from Lake Ontario and probably persists only in Lake Superior. None were collected by LMS in 1973 or 1974.

Shortnose Cisco (Coregonus reighardi)

The shortnose cisco was once a valuable commercial species in Lake Ontario until at least the 1940s. It is now very rare and only two individuals have been reported in the literature in recent years (Wells, 1969). None were collected by LMS in 1973 or 1974.

In summary, the following species will be considered as representative important species for the assessment of plant impact at the Oswego and Nine Mile Point sites:

1.	Alewife	Alosa pseudoharengus
2.	Brown trout	Salmo trutta
3.	Coho salmon	Oncorhynchus kisutch
4.	Rainbow smelt	Osmerus mordax
5.	Smallmouth bass	Micropterus dolomieui
6.	Spottail shiner	Notropis hudsonus
7.	Threespine stickleback	Gasterosteus aculeatus
8.	White perch	Morone americana
9.	Yellow perch	Perca flavescens
10.	Gammarus	Gammarus fasciatus

B. LIFE HISTORIES OF REPRESENTATIVE SPECIES

1. Alewife (*Alosa pseudohorengus*)

The alewife is an anadromous species that spends most of its adult life in marine waters and returns to fresh water to spawn. It occurs from Newfoundland to North Carolina (Scott and Crossman, 1973), and, in addition, is landlocked in many lakes along its range, including Lake Ontario.

In Lake Ontario, adult alewives reside in the open lake and migrate inshore during the spring and summer to spawn in streams or in near-shore shallow water areas with sand and gravel bottoms. During the spring spawning season, the greater numbers of alewives move inshore at night; a decrease in alewife abundance in the spawning areas during the day indicates the occurrence of short diurnal migrations near the spawning grounds. Spawning occurs at 16-28°C (60.8-82.4°F). The freshwater female may lay from 10,000 to 22,400 eggs (Odell, 1934; Norden, 1967). Mansueti (1956) noted that the eggs are broadcast at random and are demersal, essentially nonadhesive. The hatching period ranges from 48 to 96 hours at 22°C (71.6°F) and increases to six days at 15.5°C (59.9°F) (Rounsefell and Stringer, 1943). More detailed temperature data appear in Appendix A.

Following spawning, the adults move offshore into deeper waters during August and overwinter there until March (Graham, 1956). Christie (1973) noted offshore migrations of alewives to depths of 35 m (120 ft) during the late summer. Summer lethal threshold temperatures range from 3°C (5.4°F) above acclimation to a temperature of 32°C (89.6°F).

Like adults, juvenile alewives migrate inshore during the spring and undertake diurnal movements while inshore. They may be found in shallow water at night and on the bottom in 2-3 m (6-10 ft) of water during the day (Scott and Crossman, 1973). Odell (1934) noted that in Seneca Lake, New York, alewife fry migrate to mid-depth lake waters during the fall and winter. Graham (1956) also indicated that young-of-the-year alewives remain near the spawning grounds until the late larval stage; they then migrate to shallow protected areas prior to movement into deep water. The young may attain a length of 51-75 mm by the fall (Scott and Crossman, 1973).

In a study of alewife growth in Lake Ontario, Graham (1956) noted that alewives experience an early period of rapid growth, the rate of which decreases with the onset of sexual maturity at age 2 for males and age 3 for females. Pritchard (1929) reported that females grow faster than males and attain a greater size throughout their life. The adult alewife are filter-feeders and prey principally on zooplanktonic organisms such as cladocerans, copepods, ostracods, and mysids; in fresh water they therefore compete with the indigenous forage fish species for food. Alewives are also an important food source for large piscivorous fish

such as the lake trout, burbot, and salmon. Since its introduction into Lake Ontario during the 1800's, the alewife has increased substantially in abundance.

2. Brown Trout (*Salmo trutta*)

The brown trout is native to Europe and western Asia. It was introduced into North American waters during the 1800's and may be found throughout the Great Lakes region and the northeast coast of the United States (Scott and Crossman, 1973). This species is annually stocked in the New York portion of Lake Ontario by the New York State Department of Environmental Conservation.

Brown trout usually spawn during late autumn/early winter; in one study, Mansell (1966) noted that brown trout spawned during mid-October through early November in Ontario Province when water temperatures ranged from 6.7°-8.9°C (44.1-48.0°F). Spawning usually takes place in the shallow headwaters of streams over a gravel bottom, although Eddy and Surber (1960) observed that many spawned on rocky reefs along the shore of Lake Superior. The number of eggs deposited by a spawning female trout is proportional to her size: the larger females deposit more eggs.

Age and growth studies of Lake Ontario brown trout indicated that individuals of this species may live for 13 years (Marshall and MacCrimmon, 1970); brown trout reached a length of 427 mm at age 4 (Mansell, 1966). Brynildson et al. (1963) noted that the optimum temperature range is 18.3°-23.9°C (64.9-75.0°F). Additional thermal data for brown trout is presented in Appendix A. Brown trout feed upon a broad spectrum of aquatic organisms including insects, crayfish, salamanders, molluscs, and other fishes. Smaller trout may be consumed by large brown trout which may, in turn, be preyed upon by mergansers (diving ducks).

3. Coho Salmon (*Oncorhynchus kisutch*)

The coho salmon is an anadromous species which occurs naturally in the Pacific Ocean and in rivers and streams which drain northwestern North America. Attempts to establish the coho salmon in the Great Lakes were unsuccessful until the 1960's when there were reports of limited natural reproduction occurring in Michigan (Scott and Crossman, 1973). In New York State, the New York State Department of Environmental Conservation annually stocks coho salmon in tributary streams of Lake Ontario.

The spawning runs of the coho in the Great Lakes take place from September to early October, although actual spawning occurs from October to November or from November to January, depending upon the spawning run (Scott and Crossman, 1973). Swift-running tributaries with gravel bottoms are usually selected as the spawning site.

The number of eggs deposited by the female varies with size of the female, location, and year. The adults die shortly after they spawn. Eggs hatch during the early spring in 35-50 days, depending upon the water temperature. The yolk sac is absorbed by the alevins during a 2-3 week period as they remain in the gravelly stream bottom. When fry emerge, which may occur from March to July, some individuals will migrate to the sea or open lake, although most fry remain in freshwater streams or tributaries for a one-year period. Schools of salmon migrate to the ocean or lake during the spring of the year following emergence. The majority of the migratory population spends about 18 months in the lake or at sea and returns to spawn at age 3 or age 4 during the fall (Scott and Crossman, 1973).

The coho have lethal thermal thresholds of at least 2°C (3.6°F) above acclimation temperature, up to 25°C (77.0°F). Appendix A provides further thermal data. In fresh water, the young cohos feed upon insects, oligochaetes, and the young of chub and pink salmon. Large coho salmon prey primarily upon rainbow smelt and alewives; they, in turn, are prey for large birds and mammals including man, as well as the sea lamprey.

4. Rainbow Smelt (*Osmerus mordax*)

The original range of the rainbow smelt in eastern North America was restricted to the Atlantic coastal drainage basin from New Jersey to Labrador; whether or not the smelt is native to Lake Ontario is uncertain. Hubbs and Lagler (1958) believe that it is, whereas Scott and Crossman (1973) are of the opposite opinion. In either case, the first report of rainbow smelt taken from Lake Ontario was in 1931 by Mason (1933). They now occur in all of the Great Lakes and in many other Canadian and United States lakes. The smelt is an anadromous species, leaving the sea or large lakes in spring to spawn in freshwater streams. In Lake Ontario, spawning often occurs along the lake edge in shallow water on gravel shoals; Rupp (1965) believes that shore spawning may be as successful as stream spawning. Spawning runs of ripe smelt begin in March and continue through May (McKenzie, 1964). In Lake Ontario, spawning runs do not occur until water temperatures rise at least to 8.9°C (48°F) and the runs do not continue at temperatures warmer than 18.3°C (65°F).

Spawning occurs at night and the spawners move downstream to the lake during the day (Bailey, 1964; McKenzie, 1964). Smelt eggs are demersal, adhesive, and attach to bottom gravel. The number of eggs deposited is dependent upon the size of the female, ranging in number from approximately 8,000-30,000 (Scott and Crossman, 1973).

The smelt are a schooling, pelagic species and inhabit streams only during the spawning period. They are sensitive to temperature and light and remain in deep, bottom waters during the day. The lethal thermal

threshold for smelt is reported by Altman and Dittmer (1966) to be 21.5-28.5°C (70.7-83.3°F).

Smelt are carnivorous and prey upon a variety of organisms including insects, oligochaetes, crustaceans, and other fish. Smelt are, in turn, preyed upon by lake trout, walleye, perch, salmon and a variety of birds.

5. Smallmouth bass (*Micropterus dolomieui*)

Smallmouth bass are distributed in North America from southern Canada to Alabama, and west to Oklahoma (Hubbs and Lagler, 1958). Spawning occurs in streams or shallow bays from May through July usually over a period of 6-10 days. Spawning activities commence when temperature is in the range of 12.8°-20.0°C (55.0-68.0°F) egg deposition occurs primarily at 16.1°-18.3°C (61.0-65.0°F) (Scott and Crossman, 1973). The male builds a nest on a gravel or rocky bottom usually near the protection of rocks or dense vegetation. The number of eggs deposited varies with the size of the female, ranging from 5,000-14,000. Smallmouth bass eggs are demersal, adhesive, and attach to stones in the nest. Hatching takes place over a period of 4-10 days in Canadian waters (Scott and Crossman, 1973).

Initially, growth is rapid, whereas growth of older fish is variable; reported landings include a female 13 years old, 584 mm in fork length. Males attain sexual maturity in their third to fifth year; females mature in their fourth to sixth year of life.

Diet and seasonal movements occur partly in response to ambient temperature fluctuations. Adults are found in shallow water on the spawning grounds during the spring; with the onset of summer temperatures, they move to greater depths. Studies have indicated that tagged fish undertake limited migrations of 0.8-8.0 km (0.5-5 miles) from the place of capture; some males have been observed to return to the vicinity of the nest in subsequent years during the spawning season. During the winter, smallmouth bass congregate near the bottom and are relatively inactive.

Thermal data are presented in Appendix A and indicate lethal thresholds of 35°C-38°C (95.0-100.4°F) and preferred summer temperatures of 21°-27°C (69.8-80.6°F).

The diet of smallmouth bass varies with age. Bass prey upon plankton and immature insects during early life, whereas adult bass include crayfish and a variety of fish in their dietary spectrum. Predators that feed upon bass eggs and fry include yellow perch, catfish, gar pike, sunfish, and turtles. (Scott and Crossman, 1973).

6. Spottail Shiner (*Notropis hudsonius*)

The spottail shiner is distributed in North America from sections of Canada, including the Great Lakes, south to the state of Georgia and in the midwestern United States (Scott and Crossman, 1973).

This species spawns during the spring and early summer throughout its Canadian range over sandy,shoal areas at temperatures near 20°C (68.0°F) (Peer, 1961; Carlander, 1969). The number of eggs spawned varies from 100-2600 for yearlings through two year-olds (McCann, 1959). Evidence is scanty regarding the use of the mouths and lower reaches of tributary streams for spawning. During the spring, these shiners may be found inshore; they migrate toward the shore during the daytime and move into deep waters as the lake or river waters warm. Lethal thresholds after acclimation to 7°-11°C (44.6-51.8°F) temperatures are 30°-31°C (86.0-87.8°F) (Trembley, 1961); additional temperature data are found in Appendix A

Smith and Kramer (1964) noted that females grow faster than males. A maximum size of 132 mm in total length was indicated for a specimen collected from Lake Erie (Scott and Crossman, 1973).

The spottail shiner feeds upon a variety of organisms throughout its life cycle. In general, young fish prey upon small organisms including insects and cladocerans; older individuals consume their own eggs and young. As a fish of considerable forage value, the shiner is eaten by almost all predaceous species and therefore is extremely important in the trophic structure of the ecosystem.

7. Threespine stickleback (Gasterosteus aculeatus)

The threespine stickleback is widely distributed in fresh and marine waters of North America. It ranges from Chesapeake Bay north to the Hudson Bay region.

The threespine stickleback spawns during the summer (June - July) in fresh water, building its nest in shallow, sandy areas (Scott and Crossman, 1973). The male entices the female to the nest by a distinctive courtship display; eggs are then laid in clusters and are adhesive to each other. Breder and Rosen (1966) stated that hatching occurs in 7 days at 19°C (66.2°F). The males tend the eggs and the young for several days after hatching.

Growth is rapid during the first year, but slows during the second year of life, with a maximum size of 102 mm attained in fresh water. Sexual maturity is attained during the first year and the individuals probably do not live longer than 3-1/2 years.

Lethal threshold temperature is listed in Appendix A as varying from 26°-33°C (78.8-91.4°F) afteracclimation to 19°-20°C (66.2-68.0°F) temperature.

A voracious feeder, the threespine stickleback consumes various annelids, crustaceans, insects, and eggs and larvae of fish. They, in turn, are preyed upon by fish-eating birds as well as by larger fish including trout and salmon, and therefore, serve as an important forage species.

8. <u>White perch</u> (<u>Morone americana</u>)

White perch occur along the Atlantic coast of North America from New Brunswick, Prince Edward Island, and Nova Scotia to South Carolina. This species has been introduced into Lake Ontario and is common in the Hudson River below Albany, New York (Scott and Crossman, 1973).

In Lake Ontario, the white perch spawns during the spring from mid-May through June (Sheri and Power, 1968). Water temperatures during the spawning period range from 11°-15°C(51.8-59.0°F). Spawning usually takes place over a period of 1-2 weeks with successive releases of eggs during this time (Mansueti, 1961). Spawning is accomplished over a variety of substrates. The eggs are adhesive and attach to rocks, vegetation and debris. The number of eggs spawned is dependent upon the size of the female and may range from 20,000-300,000 (Scott and Crossman, 1973). Hatching is controlled by ambient water temperature and ranges from approximately 4 days at 15°C (59.0°F) to 30 hours at 20°C (68.0°F). Thoits (1958) indicated that the young attained a length of 40-65 mm by July and August.

White perch growth rates vary with region and population. Landlocked populations, such as Lake Ontario white perch, exhibit a slower growth rate. Sex differences are also indicated with respect to growth: females appear to be, on the average, slightly larger than males.

Diurnal migrations have been noted for white perch, which appear to move to offshore waters during the day and inshore during the night. Sheri and Power (1968) also observed migration to the surface at night and a descent to deeper waters during the daylight hours.

The diet of freshwater populations is composed of insects, (especially chironomids) crustaceans, annelids, molluscs, and fish. Fish, including such species as yellow perch, johnny darter and white perch, represent a significant portion of the diet of large white perch.

9. <u>Yellow perch</u> (<u>Perca flavescens</u>)

There is some question as to whether there are one, two, or three separate species of yellow perch-like fish in the Northern Hemisphere. In any case, the yellow perch and its sister species or sub-species have a circumpolar distribution in fresh water. In North America, the yellow perch occurs from Nova Scotia south along the Atlantic coast, previously to South Carolina, but now apparently to Florida and Alabama.

The yellow perch is a commercially valuable species throughout its range, and consequently there is considerable literature on various aspects of its life history. These fish are considered very adaptable because of the wide range of habitats in which they are found, including warm to cooler areas from large lakes to ponds, or quiet rivers. They are most abundant in the open water of large lakes with moderate vegetation

(Scott and Crossman, 1973). Yellow perch are usually considered shallow water fishes and are usually not collected in water depths below 9.2 m (30 ft).

Both the young and adults form loose aggregations of 50 to 200 individuals segretated by size. The groups of young are found in shallower water and nearer shore than adults. Individuals of schools of adults are close together in summer and more separate in winter (Scott and Crossman, 1973).

Scott (1955), Hergenrader and Hasler (1968), and Muncy (1962) found that yellow perch undertake a spring migratory movement. Storr (1973) reported that, in the southeastern portion of Lake Ontario, migratory movements to the spawning ground occurred in the winter. In addition, movements inshore and out, vertical diel movements, and seasonal movements into and out of deeper water have been reported. These latter movements are probably responses to temperature and distribution of food. In the bay of Quinte, Lake Ontario, yellow perch make yearly spring movements in large numbers to the spawning grounds (Griffiths, 1974).

Everest (1973) found at the Hearn Generating Station on Lake Ontario that yellow perch were concentrated in the plume area as compared to a control area, especially during October. Yellow perch were found only from June to November. During October they were collected at temperatures of from 13°-22°C (55.4-71.6°F) at a time when ambient temperatures were around 9°-11°C (48.2-51.8°F). The final temperature preference for the species has been experimentally determined at 21°-24°C (69.8-75.2°F) (Ferguson, 1958). Data from the vicinity of Nine Mile Point do not support the results obtained by Everest (1973). Statistical tests show no significant differences in yellow perch abundance near the surface (where the buoyant plume exists) or at the plant transect as compared to controls in 1974 (LMS, 1975, in preparation).

Sheri and Power (1968) estimated the fecundity of yellow perch in the Bay of Quinte, Lake Ontario, to range from 3,035-61,465 eggs for fish 131-257 mm long. Muncy (1962) reported that the fecundity of yellow perch in the Severn River varied from 5,900 eggs for a fish 173 mm in length to 109,000 eggs for one 358 mm long. Mean egg production for 20 fish ranging in size from 173-295 mm was 17,940 eggs while 5 larger females 302-358 mm had a mean egg production of 32,200 eggs.

10. Gammarus fasciatus

The amphipod Gammarus fasciatus is widely distributed in the fresh waters of North America. Its range extends from the Caribbean seacoast north to the St. Lawrence River System, and from the Atlantic coastal area as far west as the Mississippi River (Clemens, 1950).

Clemens (1950), in describing the reproductive cycle of G. fasciatus, noted that the sexes are separate and that reproduction is entirely sexual. Males are longer at the attainment of sexual maturity than females, for which the size at maturing varies with the temperature; at 6°C (42.8°F) females mature at 8.8mm, while at 26°C (78.8°F) they mature at 5.4mm. Egg production is positively correlated with body length and season. Clemens (1950) observed that the average monthly egg production per female decreased from April to September; the average number of eggs per female for the entire season was seventeen. Mature females lay eggs subsequent to each adult molt, and copulation occurs just subsequent to moulting, during ovulation, and for a short time afterward. The proximity of the two sexes at the time for fertilzation is ensured by the act of pairing, whereby the male carries the female until copulation is completed. During incubation the fertized eggs are carried in a brood pouch or marsupium under the female. The incubation period depends on temperature; at constant temperatures of 24, 22, 20, 18 and 15°C (75.2°, 71.6°, 68.0°, 64.4°, and 59°F) incubation lasted 7, 8, 9 14, and 22 days, respectively. The maximum number of incubation periods or broods produced per female per year was estimated to be seventeen in Lake Erie. However, the actual number of broods produced per female is probably between five and eleven.

Immature gammarids reached maturity after seven molts (Clemens, 1950), with the interval between molts decreasing with increased temperature. In the laboratory at 21°C (69.8°F), gammarus young required 42 to 53 days to reach maturity, whereas at temperatures varying from 14 to 22°C (57.2° to 71.6°F) young achieved maturity in 66 to 85 days.

An omniverous feeder, Gammarus fasciatus devours living and dead plant and animal matter, and may prey on such zooplankton as Daphnia, Leptodora and copepods (Clemens, 1950). It also eats benthic organisms such as insect larvae, oligochaetes, and small isopods (Burbanck, personal communication 1972); in addition, male gammarids in particular are cannabalistic. G. fasciatus plays an important role in the trophic structure of many aquatic environments since it is in turn consumed extensively by a wide variety of fish and invertebrate predators (Scott and Crossman, 1973, LMS, 1974, 1975).

Temperature tolerance data on G. fasciatus is presented in Appendix A. Pentland (1930) observed that it is capable of enduring high temperatures. Lauer et al. (1975) observed that Gammarus sp. acclimated at 25°C (77°F) suffered no mortality when exposed for 1 hr. to a temperature of 35.6°C (96°F); 92% of the organisms exposed to a temperature of 37°C (99°F) for 1 hour died within 24 hours.

VII. DISCUSSION OF POTENTIAL THERMAL DISCHARGE IMPACTS

A. INTRODUCTION

The thermal discharge from steam-electric generating stations has the potential to produce changes in the nearby aquatic communities. These effects may be direct effects due to the temperature rise of the thermal discharge, or may be indirect and more related to the method of discharge than to the thermal component. Both types of potential effects are discussed in this chapter with respect to the selected representative important species.

B. POTENTIAL DIRECT EFFECTS

1. Thermal Thresholds of Representative Species

The direct effects of heat addition on organisms are dependent on the ambient temperature of the water, the magnitude of the temperature rise, the type of discharge structure, the duration of exposure of an organism, the amount of area and/or volume affected and the kinds and physiological state of the organisms.

The life history information for the representative important species indicates species-specific responses to ambient and plume temperature. Little behavioral information on fish avoidance of or preference for thermal plumes is available.

All changes either within a fish or between the fish and its environment ultimately are initiated through a physiological response. These changes can lead to alterations of the behavior or ecological structure. More fundamentally, physiological changes within fish can be viewed as acute or latent. Acute effects generally can be equated to death while latent effects include a host of other changes including alterations in osmosis, metabolism, excretion, respiration, brain function, reproduction, growth, and so on.

The "zone of tolerance" characterizes species after acclimation as to their high or low lethal temperatures. The available information on the thermal tolerances of the representative important species is presented in Appendix A. Within this temperature range, the fish can survive, but some alterations in the physiological characteristics of the fish occur with changes in temperature.

Temperature effects can be modified by the past thermal history of the fish. Temperature acclimation is a physiological adjustment by the organism to a given thermal level. The ability to acclimate is limited within a range of temperatures. The maximum upper or lower acclimation points have been called the "ultimate incipient lethal level" by Fry (1947). When a change in temperature occurs, and the change is large enough to be of physiological significance, and when insufficient time is available for acclimation, a condition referred to as "thermal shock"

can occur. Thermal shock is characterized by disorientation and cessation of directed activities and can result from high or low temperatures. The critical thermal maximum (CTM) is the thermal point at which the locomotory activity becomes disorganized and the fish loses its ability to escape from conditions that may cause death.

Thermal studies are often conducted to determine the lethal limits or boundaries of an organism. These lethal limits are specific to a given species and for each life stage. This zone of temperature tolerance is bounded by lethal thresholds which are characterized as those temperatures at which 50% of a sample will survive. These lethal thresholds are typically referred to as "incipient lethal temperatures" and indicate the point at which temperature begins to exhibit its lethal effects.

Under natural conditions, the selection of a particular region of thermal conditions when a temperature gradient is available has been termed thermal preference. Fry (1947) further defined that temperature "around which all individuals will ultimately congregate, regardless of their thermal experience before being placed in the gradient" as the final preferendum. Ferguson (1958) presents a review of many early investigations which dealt primarily with temperature preference from field data.

Recent work has shown that the effects of temperature are influenced by a multitude of other factors, e.g., the length, weight, sex, and age of the fish as well as the photoperiod, light intensity, diet, water chemistry and salinity (Halsband, 1953; Sullivan and Fisher, 1953; Hoar, 1955; Fisher, 1958; McCawley; 1958; Hoar and Robertson, 1959; Cragie, 1963; Sprague 1963; Smirnova, 1967; Garside and Jordon 1968; Barker et al., 1970; Mildrim and Gift, 1971; Cherry et al., 1975).

The thermal data for each species have been reviewed and critical conditions for quantitative evaluation have been identified; particular attention is focused on the occurrence of lethal warm temperatures and temperature elevations.

During summer (June-September), the ambient temperature of 23.3°C (74°C) is exceeded 10% of the time (See Figure III-4); the mean summer ambient temperature is 19.4°C (67°F). The maximum discharge temperature rise of the plant is 15.9°C (28.6°F); however, this is diluted rapidly by the high velocity diffuser outfall as was described in Chapter IV. The maximum surface temperature rise above ambient is 2.6°C (4.6°F) when ambient currents are most adverse to dilution and the plant is operating at full capacity.

Temperatures warmer than the surface maximum occur between the diffuser ports and the surface plume, in the submerged jet portion of the effluent plume. These isotherms enclose much smaller plume volumes and entrain less flow than the 2.6°C (4.6°F) temperature rise observed at the surface.

The mean projected summer discharge temperature rise from the plant is 9.1°C (16.4°F); the corresponding maximum surface temperature rise for mean plant load is 1.5°C (2.7°F). The projected maximum plant load for summer is less than 80% of capacity, producing a maximum summer temperature rise near 2.1°C (3.8°F).

Thus, under mean ambient temperature and average plant load conditions, the maximum surface temperature in the plume is predicted to be 20.9°C (69.7°F), 1.5°C (2.7°F) above the summer ambient temperature of 19.4°C (68.9°F).

The summer lethal thermal thresholds for representative important species are listed in Table VII-1. Some of the associated acclimation temperatures are not specified (see Appendix A for the complete available data list); thus, the thresholds may in some cases be conservatively low due to acclimation temperatures below the normal summer Lake Ontario ambient temperature. Only four species have lethal threshold temperatures which may occur in the thermal plume downstream of the initial jet portion of the discharge. These species are the alewife, brown trout, coho salmon, and rainbow smelt.

The range of the lethal threshold reported for alewives is 23°C-32.2°C (73.4°F-90.0°F) with no specified acclimation temperature. Graham (1956) reported a 23°C (73.4°F) lethal threshold (at a 20°C [68°F] acclimation temperature) for fish immediately after rising from the cold depth where they overwintered. Preferenda, however, indicate that the alewife will migrate from the lethal temperature toward 21.3°C (70.3°F). Overwintering fish are continually under an osmotic stress and their ability to withstand a thermal stress at this time of the year is at a minimum when compared to other times of the year.

Brown trout have a lethal threshold of 23.5°-25°C (74.3°-77.0°F). The 25°C (77.0°F) threshold is associated with 14°-18°C (57.2°-64.4°F) acclimation temperatures. Summer ambient near the site exceeds 20°C (68°F) and thus the summer lethal threshold for brown trout is expected to be exceeded. The lethal threshold for coho salmon is 24°-25°C (75.2°-77°F) which is rarely exceeded by temperatures at the site. The frequency of occurrence of this lethal threshold at the water surface is about 6% of the time in the summer or about 7 days during the summer.

Summer lethal threshold reported for rainbow smelt range from 21.5°-28.5°C (70.7°-83.3°F). The lower range is not applicable since summer ambient temperatures sometimes exceed 25°C (77°F) during the period when smelt are present in the area, yet no die-offs are observed. At maximum ambient temperatures, 26.7°C (80°F), the upper end of the lethal range, 28.5°C (83.3°F), corresponds to a 1.8°C (3.3°F) temperature rise.

The summer lethal temperatures are nearer to the acclimation temperatures for all species except white perch which have a winter upper lethal threshold of 6.6°C (43.9°F) and a summer upper lethal threshold of 34.7°C (94.5°F). In order to evaluate accurately direct thermal effects on

TABLE VII-1

SUMMARY OF LETHAL THRESHOLDS TEMPERATURES

Species	Summer Lethal Threshold
Alewife	23°-32.2°C (73.4°-90.0°F)
Brown Trout	23.5°-25°C (74.3°-77.0°F)
Coho Salmon	24°- 25°C (75.2°-77.0°F)
Rainbow Smelt	21.5°-28.5°C (70.7°-83.3°F)
Smallmouth Bass	35°C (95°F)
Spottail Shiner	>30.8°C (>87.4°F)
Threespine Stickleback	25.8°-33°C (78.4°-91.4°F)
White Perch	34.7°C (94.5°F)
Yellow Perch	29°-32°C (84.2°-89.6°F)
Gammarus	none available

all species, Chapter VIII includes an estimate of monthly average cropping due to thermal stress based on a "worst case" evaluation of available thermal data.

The summary provided above and the evaluations in Chapter VIII are expected to overestimate the plume impact since thermal preference data and fish avoidance studies consistently support the concept that fish avoid lethal temperatures. This concept has not been used in these evaluations since (1) fish behavior is difficult to quantify and (2) the assumption that fish do not avoid the lethal temperatures assures that this demonstration (Chapter VIII) overestimates the plumes impact on the representative species.

2. Shut-down Effects

The temperature data sheets (Appendix A) include limited lower lethal threshold data. Sensitivity to temperature decreases is greater than that due to increased temperatures. The most sensitive species is the alewife which has a reported lethal threshold of 0.2°C (32.4°F) at 5°C (41°F) acclimation temperature. During the period in mid-winter when the lake ambient temperature is near 0.2°C (32.4°F), alewife might be expected to suffer some mortality if the plant shuts down abruptly and if the alewife have not responded to the preferred temperatures by moving offshore into 4°C (39°F) mid-lake waters. Quantitative evaluation of fish affected by shutdown depends on the plume size and velocities at that time as summarized below.

During the winter the plant will temper its cooling water so that the condenser inlet temperature is maintained near 7.2°C (45°F). The projected maximum discharge temperature (90% plant load) when ambient temperature is near 0°C (32°F) is 21.2°C (70°F) or 21°C (38°F) above the ambient temperature. At mean winter load the discharge temperature is 8.7°C (47.7°F), or 8.7°C (15.7°f) above ambient temperature.

The potentially lethal 5°C (9°F) isotherm corresponds to 4:1 effluent dilution and will encompass a volume with velocities which are expected to preclude fish residency. The tempered flow will amount to an estimated 11.9m^3/sec (420 ft^3/sec) resulting in an exit velocity of 3.4m/sec (11.1 fps). The 4:1 dilution contour is estimated to enclose velocities in excess of 0.8m/sec (2.8 fps). Few, if any fish, can maintain themselves in such velocity fields in winter. Hence, the effect of plant shutdown in winter is not predicted to affect even those fish which may attempt to establish residency in the plume due to the high velocity of the plume. Fish which pass through the plume are affected as described for the summer plume; mortality is assumed for the conservatively estimated lethal temperature elevation. Quantitative estimtes of this impact are provided in Chapter VIII.

C. POTENTIAL INDIRECT EFFECTS

1. The Effects of Currents, Shear Forces, Pressure Changes, and Dissolved Oxygen

The discharge of water by a submerged jet diffuser can have the following possible effects:

1. the production of currents which may act as a near-field attractant to fish,

2. water movements which cause the passive movement of fish eggs and larvae into the dispelled waters (plume entrainment) and hence subject these organisms to thermal stress,

3. the movement of the plume-entrained organisms toward the surface waters with the heated water and a resultant decrease in the pressure to which these organisms must accommodate,

4. shear forces created by the movements of water masses in differing directions which can damage the internal structure of a fish egg or larva, and

5. potential reduction in dissolved oxygen by biological oxygen demand or heating.

That fish orient themselves with water currents has been known at least since Gudger (1949) described a group of trout (Salmo gairdneri) arrayed in extremely regular ranks near the bottom of a swiftwater stream. Breder (1959) generalizes, for schools of fish in flowing water, that "it must be remembered that it is possible to arrange the distribution and form of the schools into almost any outline desired by suitable adjustment of the amount of flow and its direction." Thus, the currents created by the discharge diffuser may assume patterns which, in the near field, affect the orientation of fish. Kelso (1974), working with several species of fish in the vicinity of two Canadian power plants, concludes that the fish were attracted by the currents produced by the discharge rather than by its heat. He found that the fish made what appeared to be feeding forays into the heated areas, remained there for some 20 minutes, and then left the area. This behavior occurred both when the plants were rejecting heat and when the circulating pumps were operating but no heat was being discharged. Insufficient quantitative information precludes an assessment of this impact on fishes but the food web of fish near the plume is not expected to differ from the natural habits of the fish, thus no net change in fish abundance can be related to the thermal discharge.

The early life stages of fish can also be affected by entrainment into the plume, where they are subjected to heat. In addition, as the heated water rises, the planktonic organisms within the water column will also rise and be exposed to a change in pressure. It is estimated that the

Oswego Unit 5 cooling water will reach the surface in approximately 30 seconds from a depth of 8.5m (28 ft), thus subjecting the entrained organisms to a hydrostatic pressure change from 2 atm at 9.1m (30 ft) to 1 atm at the surface at a rate of 0.03 atm/sec.

Tsvetkov et al. (1972), after studying the effects of hydrostatic pressure changes on fish, concluded:

1. acclimation of fish to a pressure is critical in determining mortalities resulting from rapid changes in pressure,

2. for fish survival, the rate of pressure change is more important than the magnitude of the pressure applied,

3. injury and mortality, especially in physoclists (fish without connection between air bladder and gut), occurs when the pressure release rate is greater than the normal decompression rate for fish,

4. rapid pressure changes can effect physostomous fish (fish with functional connection between gut and swim bladder), and

5. sensitivity to rates and magnitudes of pressure changes is greater for the young of fish with developed swim bladder than for older fish.

Most investigations of the effects of pressure on fishes have dealt with the lethal thresholds of increasing pressure while little has been published on the effects of a reduction of pressure toward atmospheric pressure.

Tsvetkov et al. (1972) exposed both physostomous and physoclist fishes to modeled changes in the magnitude and rates of change of hydrostatic pressure during passage through turbines. Pressures from 1-6 atmospheres were applied by air pressure to the surface of the water in order to acclimate the fish, which were allowed to adapt to neutral buoyancy. The perch (Perca fluviatilis), a physoclist, required 23-27 hours to acclimate to neutral buoyancy at one atmosphere, and at least 72 hours at 3 atmospheres. The physostomous fishes were unable to acclimate, when access to an air-water interface was restricted. The rates of releasing pressure to atmospheric ranged from 0.1-6 atm/sec. To observe possible delayed mortalities, all surviving fish were maintained up to four days.

Swim bladder injury and gas disease were the causes of pressure-induced mortalities. Death occurred within 10 seconds to 15 minutes after rapid release from the acclimation pressure, when rupturing of the swim bladder wall occurred. In the physostomous fishes, no swim bladder damage was observed when the rate of pressure release was retarded, but rupturing of other internal organs did occur as the swim bladder expanded, compressing the other organs. Fingerlings of the roach Rutilus rutilus

(L.) [a physostome] displayed 100% mortality at a pressure release rate of 3 atm/sec, 40-72% mortality at 0.1-0.5 atm/sec, and 10% mortality when the rate was below 0.1 atm/sec.

Generally, the physostomes, including the alewife and rainbow smelt, will not be adversely affected by the reduction of 0.03 atm/sec expected to occur within the rising discharge waters. In addition, it is unlikely that this rate of pressure reduction would adversely affect the physoclists, e.g., the white perch, yellow perch, and spottail shiner.

The impacts calculated in Chapter VIII however assume 100% mortality of organism entrained into the warmest plume isotherms. The same warm isotherm enclose the zone of maximum pressure change, hence the assessments made for the 3°C (5.4°F) isotherm in the plume may be considered to include any possible effects of rapid changes in pressure.

Lastly, shear forces produced by the differential current movements may result in an additional stress on fish eggs and larvae. The maximum shear force expected to occur between the 2.5°C (4.5°F) isotherm and the ambient temperature water is 1.33 dynes/cm^2. The shear between the 0.3°C (0.5°F) isotherm and the ambient water is 0.09 dynes/cm^2. Morgan et at. (1973) have reported that striped bass larvae could withstand shear of 3.4 dynes/cm^2 for 1 min. in a specialized apparatus with laminar flow. Although this species is not present in Lake Ontario, the shear stress it can withstand before injury is applicable to the species in the vicinity of Oswego Steam Station. Therefore, it appears that little or no adverse impact can be expected to occur as a result of shear forces within the thermal plume.

The effect of the thermal component of the discharge on levels of dissolved oxygen has been considered. Two factors could cause a reduction in the oxygen concentration as the cooling water passes through the condenser system of Oswego Unit 5:. sudden reduction in pressure, and heat. In addition, rising temperature affects oxygen demands. Bioligical Oxygen Demand (BOD) increases about 2% for each 1°C (2°F) rise above 20°C (68°F) (FWPCA, 1967).

Fish eggs, larvae, and adults require oxygen concentrations of at least 2-4 mg/l for sustained growth and reproduction, although the exact quantity depends on the species. Values this low are rarely, if ever, found in the vicinity of Oswego Steam Station Unit 5 discharge (LMS, 1974).

Oxygen concentrations recorded by QLM in 1973 ranged from 9.2 to 10.2 mg/l (QLM, 1974a). With a subsequent increase in temperature of 4°C (7.2°F) the expected level would be 8.5 to 9.4 mg/l (Fair, Geyer and Okun, 1968). These values are well within the acceptable range for survival, growth, and reproduction of the fishes present.

Specific studies have been conducted at Nine Mile Point Unit 1 to quantify the dissolved oxygen reduction on passage through the power plant. Analyses of the 1973 data documented that the reduction average 0.3 mg/l even though the inlet water was supersaturated. It is proposed that the reduction was slight due to the rapid passage of water through the plant.

D. SUMMARY

The potential direct and indirect effects of the thermal discharge from Oswego Unit 5 were presented. Although quantitative information regarding many of these factors and their effects on aquatic organisms is insufficient to determine the magnitude of the impact, information was presented that indicated that the effects did not result in 100% mortality. For the purposes of this demonstration, however, it is conservatively assumed that all organisms that are entrained or enter into thermally lethal portions of the plume will suffer 100% mortality regardless of their exposure time or other mitigating factors. Since the warmest portions of the plume include those portions where maximum pressure change and shear occur, the mortality assumption for thermally lethal isotherms includes the possible effects of pressure and shear as well. The assessments for these temperatures are quantified and discussed in Chapter VIII.

VIII. IMPACTS OF THE DISCHARGE

A. INTRODUCTION

This chapter presents quantitative estimates of the impact of the thermal discharge (described in Chapter IV) on the aquatic biota within the adjacent water body segments defined in Chapter III. The evaluations are specific for those representative important species selected by the EPA (see Chapter VI). The evaluations are based on characteristic plume isotherms of 2° and 3°C (3.6° and 5.4°F) above ambient and on the species thermal data summarized in Chapter VII, and tabulated in Appendix A. The assessment presented herein utilized baseline data available from the aquatic studies conducted in the vicinity of the site (see Chapter V). These data were quantified for the representative important species in each water body segment.

Four important numbers are calculated for each water body segment and used to evaluate the impacts of the discharge on the representative important species. These are: (1) the concentrations by month of larvae and fish in each water body segment, (2) the volume associated with potential exclusion zones of the 2° and 3°C (3.6° and 5.4°F) ΔT isotherms, which are related to potential lethal thresholds for some of the representative species, (3) the areas associated with various ΔT isotherms, and (4) the flux cropping ratio (cropping rate/the flux of organisms).

All fish and larval data collected during 1974 were reduced to concentrations [number of organisms per 1000 m^3 (35,288 ft^3)]. Fish data were available from trawl, gill net, and beach seine surveys. The trawls collected low numbers of fish. The beach seines collected the smaller fish which reside in the nearshore waters. The large numbers of fish and the high species diversity of the gill net collections indicate that they sample a wide spectrum of species. In addition, these collections were made in water depths commensurate with the water depth at the outfall.

The chapter is organized in a step-wise fashion. The evaluations are presented in the following order:

1. The methods used in determining fish and larval concentrations in the water body segments.

2. The estimation of the potential exclusion zone for Oswego Unit 5.

3. The estimation of the cropping rate of larvae due to plume entrainment of Oswego Unit 5.

4. The estimation of cumulative cropping of larvae due to plume entrainment of Oswego Unit 5, Nine Mile Unit 1 and the Fitz-Patrick unit.

5. The estimation of the cropping rate of fish due to plume entrainment of Oswego Unit 5.

6. Cumulative effects of all stations on each water body segment.

B. CONCENTRATIONS OF FISH AND LARVAE IN THE ADJACENT WATER BODY SEGMENT

Catches from gill nets set in the vicinity of Oswego were used to estimate fish concentrations in water body segment I. These data combined with similar data for the Nine Mile Point area were used to estimate concentrations in water body segment II. It is assumed that gill net data are representative for six of the nine species of concern: alewives, rainbow smelt, spottail shiners, white perch, yellow perch, and smallmouth bass. Gill nets did not effectively catch threespine sticklebacks, coho salmon, or brown trout. Threespine stickleback populations were calculated from other data as described later in this section. Very few coho salmon or brown trout were collected in the field sampling programs and, therefore, no reliable estimates of concentrations for these species are available.

Gill net data is recorded as catch per twelve hour effort. The area of each gill net (11.2 m^2, 120 ft^2) and the sample period (12 hrs) is known; however, because fish are swimmers, they are not generally carried through the net by the ambient current. It was, therefore, necessary to estimate swim speeds and to treat this as a flow through the net, that is, the catch is related to the swim speed as water flow is related to velocity.

Two swim speeds were used to provide concentration estimates, 2 cm/sec (0.07 fps) and 12 cm/sec (0.39 fps). These values encompass, within a width of two standard deviations, the average swim speed for yellow perch and white sucker calculated from data collected by Kelso (in press). It is realized that the average speed at which a fish swims is dependent on a number of factors, e.g., the species, size, age, temperature, etc; however, for the purpose of this demonstration the generalization was made that these six species swim at speeds in the range cited. Further, it is realized that gill nets do not catch all fish species with equal efficiency. Nevertheless, the use of swim speed data and gill net catch per effort data allow for a relative abundance estimate that is not available otherwise. The lake concentrations were calculated using a 2 cm/sec swim speed for the six species.

Threespine sticklebacks were not caught in gill nets or trawls and the swim speed approach described above was not possible for this species. This fish is territorial during the spawning period, and this behavior is utilized to estimate its population. Threespine sticklebacks spawn in shallow vegetated zones and occupy an area at about 0.42 m^2 (4.5 ft^2) (Black and Wooten, 1970). Divers working near the Oswego station have reported that vegetation grows over about 50% of the bottom to a depth of about 5-6 m (16-20 ft).

If it is assumed that all of the available suitable area is occupied by threespine sticklebacks, then the population estimate for threespine stickleback would exceed that of alewives by a factor of 25. Therefore, the population is probably conservatively estimated if it is assumed that only 1-10% of the available area is occupied. The method used in this report is to assume that 2% of the area is used and that each territorial male is accompanied by a female.

The calculated concentrations of coho salmon and brown trout (Tables VIII-1a and 1b) are zero or near zero due to the small numbers collected in the field studies. New York State is currently stocking these species, although their capacity for self-propagation in Lake Ontario is doubtful and not documented. No concentrations are available for these species but recent annual stocking data are utilized. In the absence of population estimates the stocking program serves as a basis for comparison with the plant impact. In 1974 the state stocked 42,000 brown trout and 500,000 coho salmon in Lake Ontario.

Larval concentrations were calculated by averaging all larval tow data within a segment by month. The larval tows were conducted with flow meters so that, unlike the gill net data, the larvae concentrations were calculated directly from field data. Only alewife, rainbow smelt, white perch, and yellow perch larvae were collected in the ichthyoplankton tows in the Oswego area. The fish and larval concentrations for lake water body segments I and II are presented on Table VIII-1.

C. THE RELATIVE EFFECT OF POTENTIAL FISH EXCLUSION ZONES

1. Introduction

The calculation of discharge plume characteristics is described in Chapter IV. The estimates for plume parameters are based on hydraulic model test results and a plume model. The plume analysis provides values of plume volume within ΔT isotherms, V_T, entrained, and other relevant values. The discharge parameters for capacity operation and for seasonal average loads are summarized in Table IV-5. The portion of the water body segment occupied by the plume may be unsuitable for habitation by certain fish species. For the purposes of this documentation two alternative isotherms are used to characterize the plume, the 2° and 3°C (3.6° and 5.4°F) temperature rise isotherms. Most fish species are not lethally sensitive to such small temperature elevations. For those which are sensitive, this lethal temperature elevation only occurs in the summer. Fish species, however, do respond to temperature gradients. The thermal data for representative species show some preferred temperatures as well as lethal thresholds; the preferenda range from 2° to 10°C (3.6° to 18°F) below the lethal thresholds. The preferenda infer that fish will generally avoid lethal temperatures in open water

TABLE VIII-1a

CONCENTRATION OF LARVAE IN THE WATER BODY SEGMENT 1

(UNITS - NO PER THOUSAND CUBIC METERS)

SPEC.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
ALWF	********	********	********	0.0	0.0	5.8366	21.5784	129.7529	4.0696	0.0	********	********
RBSM	********	********	********	0.0	0.3000	2.5300	1.6432	0.2333	0.5667	0.0	********	********
SPSH	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	0.0	********	********
TSSB	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	0.0	********	********
WTPC	********	********	********	0.0	0.0	2.4157	0.5344	1.0500	0.0417	0.0	********	********
YLPC	********	********	********	0.0	1.6000	0.0	0.0	0.0	0.0	0.0	********	********
SMBS	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	0.0	********	********
CHSL	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	0.0	********	********
BNTT	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	0.0	********	********

SPECIAL SYMBOL ******** MEANS NO DATA

CONCENTRATION OF FISH IN THE WATER BODY SEGMENT 1

(UNITS - NO PER THOUSAND CUBIC METERS)

ASSUMED SPEED OF FISH IN THE LAKE = 2 CM/SEC

SPEC.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
ALWF	********	1.0000	********	3.8438	1.4457	3.1582	2.2683	0.1318	0.0471	0.0119	********	********
RBSM	********	********	********	0.0341	0.0029	0.0028	0.0	0.0	0.0023	0.0036	********	********
SPSH	********	********	********	0.0024	0.0083	0.0208	0.0105	0.0104	0.0104	0.0104	********	********
TSSB	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	0.0	********	********
WTPC	********	********	********	0.0313	0.0209	0.0831	0.0519	0.0311	0.0312	0.0311	********	********
YLPC	********	********	********	0.0019	0.0035	0.0208	0.0208	0.0104	0.0104	0.0035	********	********
SMBS	********	********	********	0.0019	0.0030	0.0104	0.0017	0.0043	0.0006	0.0	********	********
CHSL	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	0.0	********	********
BNTT	********	********	********	0.0005	0.0	0.0	0.0	0.0	0.0	0.0	********	********

SPECIAL SYMBOL ******** MEANS NO DATA

TABLE VIII-1b

CONCENTRATION OF LARVAE IN THE WATER BODY SEGMENT 2

(UNITS - NO PER THOUSAND CUBIC METERS)

SPEC.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
ALWF	********	********	********	0.0	0.0	17.4203	191.6749	480.3027	6.5237	0.0	********	********
RBSM	********	********	********	9.9971	39.7842	13.3340	7.8914	1.1196	0.2834	0.0	********	********
SPSH	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	0.0	********	********
TSSB	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	0.0	********	********
WTPC	********	********	********	0.0	1.0000	10.2137	3.2648	4.5250	0.2209	0.0	********	********
YLPC	********	********	********	0.0	1.3000	0.5000	1.5206	0.0	0.0	0.0	********	********
SMBS	********	********	********	0.0	0.0	0.0	0.1250	0.0	0.0	0.0	********	********
CHSL	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	0.0	********	********
BNTT	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	********	********	********

SPECIAL SYMBOL ******** MEANS NO DATA

CONCENTRATION OF FISH IN THE WATER BODY SEGMENT 2

(UNITS - NO PER THOUSAND CUBIC METERS)

ASSUMED SPEED OF FISH IN THE LAKE = 2 CM/SEC

SPEC.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
ALWF	********	********	********	2.1739	0.8539	1.7829	1.5837	0.2759	0.0897	0.0467	********	********
RBSM	********	********	********	0.1761	0.0277	0.0051	0.0004	0.0005	0.0023	0.0053	********	********
SPSH	********	********	********	0.0078	0.0103	0.0194	0.0198	0.0122	0.0064	0.0261	********	********
TSSB	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	0.0	********	********
WTPC	********	********	********	0.0178	0.0163	0.0501	0.0400	0.0212	0.0317	0.0215	********	********
YLPC	********	********	********	0.0039	0.0042	0.0114	0.0120	0.0054	0.0044	0.0035	********	********
SMBS	********	********	********	0.0006	0.0009	0.0003	0.0008	0.0012	0.0012	0.0024	********	********
CHSL	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	0.0	********	********
BNTT	********	********	********	0.0	0.0	0.0	0.0	0.0	0.0	0.0	********	********

SPECIAL SYMBOL ******** MEANS NO DATA

bodies such as those surrounding the Oswego plume. Thus, the exclusion volume and areas described in subsequent sections represent portions of the water body segments which may be made unsuitable for some fish, but not zones which are expected to induce fish mortality.

2. The Relative Effect of the Thermal Exclusion Volume

The volume of water contained within ΔT isotherms can be compared to the selected water body segment volumes in order to estimate the percentage of the water body segment affected by heat. A volume ratio, R_V, is defined as:

$$R_V = \frac{V_T}{V_{wsi}} \times 100.0 \qquad \text{(VIII-1)}$$

where V_T is the volume of water calculated to be contained within the ΔT isotherm, and V_{wsi} is the water body segment volume (i= I, II). This ratio is calculated based on the results presented in Chapter IV and the values are summarized by season in Table VIII-2. As shown in this table the volume of water heated diminishes rapidly as the warmer ΔT isotherms are approached. Furthermore, the ratio, R_V, indicates that these volumes do not constitute a significant portion of either of the water body segments. Specifically, the 2°C (3.6°F) T isotherm encloses 3/100,000ths of the small segments volume. This is comparable to a drop of water in a fifteen gallon tank. The volume enclosed in the 3°C (5.4°F) ΔT isotherm is orders of magnitude smaller than the volume of the large water body segment (WSII) and thus the impact on segment II is about one-tenth that of WSI.

The hottest ΔT isotherm in the surface plume at capacity plant operation is 2.5°C (4.5°F) due to the rapid dilution achieved by the diffuser. Based on data from chapters III and IV the volume in the plume that is raised to this amount or more is less than five ten-thousands of one percent (<0.0005%) of the volume of WSI.

The volume that is heated by 1°C (1.8°F) ΔT is less than one-hundredth of one percent (<0.01%) of WSI and less than one one-thousandth of one percent (<0.001%) of WSII. The ΔT isotherms which may be hazardous to fish, 2° and 3°C (3.6° and 5.4°F), contain even smaller volumes than those of 1°C (1.8°F) (see Table VIII-2 and Table IV-3). At mean summer plant load (53.4%) the impacted volume of 1°C (1.8°F) heating is reduced to an estimated volume 10% of that cited above since the discharge to temperature elevation is reduced by nearly half. The above numbers are based on capacity operation of Owsego Unit 5. Seasonal reductions of these volumes will result from lower than 100% load factors as predicted in Chapter II and described in Table VIII-3.

3. Maximum Potential Benthic Exclusion Areas

Many fish species congregate near the bottom and threespine stickleback spawn on the bottom. During the entire summer and much of fall, winter, and spring the heated plume will be buoyant and will rapidly rise from

TABLE VIII-2
SEASONAL POTENTIAL EXCLUSION VOLUMES

SEASON	PLANT LOAD (%)	TEMPERATURE RISE (°C)	VOLUME (m^3)	Ratio Rv[1] WSI (%)	Ratio Rv[1] WSII (%)
	Capacity	2	$2.28x10^4$	0.00341	0.00024
		3	$0.26x10^4$	0.00039	0.00003
Summer	53.4	2	$0.25x10^4$	0.00037	0.00003
		3	$0.21x10^4$	0.00031	0.00002
Fall	70.2	2	$0.26x10^4$	0.00039	0.00003
		3	$0.23x10^4$	0.00034	0.00002
Winter	48.7	2	$0.25x10^4$	0.00037	0.00003
		3	$0.21x10^4$	0.00031	0.00002
Spring	30.0	2	$0.21x10^4$	0.00031	0.00002
		3	$0.16x10^4$	0.00024	0.00002

(1) Volume WSI = $0.6692 \times 10^9 m^3$; WSII = $9.5550 x 10^9 m^3$

TABLE VIII-3

MAXIMUM PLUME ENTRAINED FLOWS AND FLOW RATIOS

SEASON	PLANT LOAD (%)	TEMPERATURE RISE (°C)	FLOW, Q_T (m^3/sec)	Ratio R_Q (1) WSI (%)	WSII (%)
	Capacity	2	78.7	2.94	0.57
		3	8.7	0.32	0.06
Summer	53.4	2	8.4	0.31	0.06
		3	7.2	0.27	0.05
Fall	70.2	2	8.8	0.33	0.06
		3	7.8	0.29	0.06
Winter	48.7	2	8.3	0.31	0.06
		3	7.1	0.27	0.05
Spring	30.0	2	7.2	0.27	0.05
		3	5.4	0.20	0.04

(1) Flow rate $_{WSI}$ = 2677 m^3/sec; $_{WSII}$ = 13800 m^3/sec

the bottom to the surface. The benthic area that is exposed to heated water is that portion of the bottom area nearest the diffuser, and in which buoyancy has not yet overcome the discharge momentum. As the plume heat and momentum are diluted, the plume separates from the bottom and spreads on the surface. Thus, the bottom is exposed only to the coolest temperature rise isotherms, and the heated benthic area is smaller than the heated surface areas for the 1° and 2°C (1.8° and 3.6°F) ΔT isotherms.

The surface isotherms are illustrated in Figure IV-1. The surface area of the 2°C (3.6°F) ΔT isotherm is approximately 9300 m^2 (100,000 ft^2) and the 3°C (5.4°F) ΔT isotherm area is less than 930 m^2 (10,000 ft^2). These areas represent two hundredths of one percent (.02%) and two-thousandths of one percent (0.002%), respectively, of the surface area of WSI. The heated benthic areas will represent an even smaller portion of the available area. The potential impact of bottom temperature rises on threespine stickleback spawning can be estimated if one assumes that 2°C (3.6°F) heating is deterimental to such reproductive activity. In this case, the portions of the potential spawning grounds affected within the water body segments are those cited above if the plant operates at full capacity during the spawning season. The spring and summer plant load factors (30% and 53%, respectively) would reduce these insignificant numbers still further.

No fish are known to spawn in the discharge area during winter but fish residence may be affected by the winter bottom temperatures. The plume is not expected to rise as rapidly during the colder months as during warmer periods because mixing of the heated effluent with lake water at ambient temperatures may produce water of greater density than ambient; however, tempering of intake water (the intentional recirculation of heated discharge) will raise the plume ΔT but decrease the rate of heated water flow into the lake. The winter plume studies cited in Chapter IV predicted winter plumes with bottom areas several times the summer surface plume size for the temperature elevations of 2°C (3.6°F). The bottom plume, however, is still a minimal fraction of either water body segment. The heated areas described above are the probable upper bounds for heated bottom areas, since the seasonal load factors are all substantially below 100% and the winter average load factor in particular is below 50%.

D. THE RELATIVE EFFECT OF PLUME ENTRAINMENT ON PASSIVE ORGANISMS

1. Plume Entrainment By Unit 5

The earlier sections of this chapter describe potential fish impacts due to heating a small portion of the naturally available water body segments. The following comparison of plume entrainment with the flux of fish in the water body segments is based on the assumption that some species are entrained into the plume, or due to peculiar behavioral habits, venture into lethal regions of the plume with the entrained dilution flow. The evaluations are more realistic for ichthyoplankton

and gammarus which have limited mobility and are conservative for fish since they are not passively transported.

It must be noted that the above discussions apply to larvae in general in the absence of species specific larval thermal tolerance data. The larvae mortality may thus be conservatively estimated at 0.3% for WSI.

It is assumed that organisms are entrained with the lake water in the same concentrations at which they exist in the lake (Table VIII-1). A comparison of the number of plume entrained organisms to the abundance of available organisms can be performed by defining a ratio of fluxes, R_Q, as:

$$R_Q = \frac{C_L Q_e \ (T)}{C_L Q_L} \times 100 = \frac{Q_e \ (T)}{Q_L} \times 100 \qquad \text{(VII-2)}$$

where $Q_e(T)$ is the entrained flow into the ΔT isotherm, and Q_L is the lake flow through the water body segment. The ratio, R_Q, describes the percentage of the available organisms, those passing by the discharge zone, that are drawn into the plume, and depends only on the ratio of the flows. The entrained flows and the flow ratios for capacity plant operation and seasonal average plant loads are summarized in Table VIII-3. These ratios are calculated using an assumed longshore current speed of 0.1 knots (5.2 cm/sec, 0.17 fps) as described in Chapter III. Assumption of a higher longshore current speed proportionately decreases the flow ratio and a lower speed increases the flow ratio. The 5.2 cm/sec (0.17 fps) speed utilized is exceeded 90% of the time for a 1 day period. The proportion of the water body segment flow entrained within the discharge plume is linearly extrapolated from the plume data and may range as high as 3%.

The flux ratio for full capacity plant operation for entrainment into a 3°C (5.4°F) ΔT isotherm is less than 0.3% and into a 2°C (3.6°F) ΔT isotherm is 3% in WSI. The comparable values for WSII are 0.06% and 0.6%, respectively, for Unit 5 operation. This could be interpreted as follows. If mortality is certain for an organism entrained into a 3°C (5.4°F) ΔT isotherm, then it is expected that an upper bound on heat-induced mortality (in WSI) is 0.3% of the available population. If the 2°C (3.6°F) ΔT isotherm is assumed to be fatal to all organisms, the resultant mortality in WSI would be about 3% of the available population. At mean summer plant load, the most conservatively estimated lethal ΔT isotherm only crops about 0.3% of the population.

It must be noted that the above discussions apply to larvae in general in the absence of species specific larval thermal tolerance data. The larvae mortality may thus be conservatively estimated at 0.3% for WSI.

2. Plume Entrainment by All Thermal Discharges in Segment II

The calculations summarized above document the minimal impact which the Oswego Unit 5 thermal plume is predicted to have on either water body segment. The larger segment (WSII), however, includes the plumes

of Nine Mile Point Unit 1 and the James A. FitzPatrick plant. This section summarizes the calculated flux cropping ratios due to plume entrainment for combined operation of all plants at full capacity, and for seasonal loads of Oswego Unit 5 in conjunction with capacity operation of Nine Mile Point Unit 1 and the FitzPatrick plant.

A detailed hydrodynamics plume model for the Unit 1 discharge has not been formulated, but its heat load is within 3% of the Oswego Unit 5 heat load at capacity operation. Heat rejection is the key parameter for quantification of plume entrainment rates. In order for a given heat load to be diluted to 3°C (5.4°F) ΔT a given dilution flow rate is required. Since the entrained flow rate is practically independent of the discharge mode, the heat load divided by the dilution flow rate plus discharge rate gives the average temperature within the 3°C (5.4°F) ΔT isotherm. For the purposes of these composite impact calculations, the plume entrainment rate for various temperature elevations and seasons are prorated to entrainment rates into all three plumes in the segment (WSII).

It should be noted that the above assumption of entrained flow rate being proportional to the heat load does not infer a similar proration of plume sizes. The Nine Mile Point Unit 1 plume is relatively large due to its low velocities and low entrainment velocities. It is assumed for this demonstration that the plume perimeter is large enough to compensate for the low velocities in such a way that the entrainment rate into a specified ΔT isotherm is the same as the flow rate for any other thermal discharge with equal heat rejection, such as that of Oswego Unit 5.

Seasonal entrainment rates into 2° and 3°C (3.6° and 5.4°F) ΔT isotherms throughout WSII are listed in Table VIII-4. Due to the large size of the segment, the average entrainment rate into the 2°C (3.6°F) ΔT isotherm is 0.35% of the flow through the segment.

The rates are near 0.3% throughout the year, but only 0.04 to 0.06% (see Table VIII-3) of the 0.3%, or about one sixth, is attributable to Oswego Unit 5 due to its load factor. Capacity operation of Nine Mile Point and the FitzPatrick plant was assumed in these evaluations. If seasonal loadings of the Nine Mile Point Unit 1 and FitzPatrick stations were used in the analysis the net impact on WSII would be substantially lower than the cropping ratios cited in Table VIII-4.

The composite values calculated above for WSII are nearly identical to the factors computed for operation of Owsego Unit 5 on WSI. For this reason species specific calculations for all months are not necessary for both segments to estimate composite impacts of all stations in WSII on the representative species. The following section describes the species-specific cropping calculated by month for entrainment into the Oswego Unit 5 plume relative to the flux through WSI.

TABLE VIII-4

COMPOSITE CROPPING BY PLUME ENTRAINMENT IN SEGMENT II

SEASON	OSWEGO 5 HEAT LOAD (%)	TEMPERATURE ELEVATION (°C)	ENTRAINED FLOW ALL PLANTS(1) (m^3/sec)	SEGMENT II CROPPING RATIO(2) (%)
	Capacity	2	269.1	1.95
		3	29.7	0.22
Summer	53.4	2	45.6	0.33
		3	39.1	0.28
Fall	70.2	2	40.4	0.29
		3	35.8	0.26
Winter	48.7	2	48.5	0.35
		3	41.5	0.30
Spring	30.0	2	56.8	0.41
		3	42.6	0.31

(1) Oswego Unit 5, Nine Mile Point Unit 1, FitzPatrick

(2) Flow ratio in WSII = 13800 m^3/sec

3. Oswego Unit 5 Impact on Representative Important Species

Species specific interpretation of the plume entrainment rates are dependent on the thermal sensitivities of the species (as described in Chapter VII and Appendix A) and the behavior of the species. Those fish for which both temperature preferenda and lethal thresholds data are available exhibit 2° to 10°C (3.6° to 18°F) differences. Thus, fish are expected to avoid the lethal portions of the plume. Some fish, however, may suffer sublethal damage at cooler temperature elevations, be pursued into the plume, or may "accidentially" be entrained into the plume due to disorientation by waves or in pursuit of food. Although information cited in Chapter VII infers that fish will generally avoid lethal conditions, the plume impacts on fish have been quantified below using the entrained flow rates into the plume and the species specific thermal tolerance data.

Upper lethal thresholds for alewife range from 20°C (68°F) in spring or fall (10°C [50°F] acclimation temperature) to 26.7-32.2°C (80.1°-90°F) in summer. Table VIII-5 lists mean ambient temperatures, estimated lethal thresholds, and the calculated cropping ratios for each month. The annual average cropping is estimated by computing the mean cropping rate weighted by the relative concentrations present each month. The average rate for alewife over the April through October period for which data are available is only 0.05%. Plant operation during the spring period of high alewife abundance at Oswego does not produce lethal temperatures in the plume. For purposes of comparison this rate can be interpreted relative to natural variations in concentrations from year to year and natural fluctuations between areas. Concentrations from year to year fluctuate as much as 200 to 800% and between Nine Mile Point and Oswego by as much as 10 to 20%.

Brown trout exhibit optimal growth in the range 8 to 24°C (46.2 to 75.2°F); the lethal threshold is above but near the upper end of this range. Cropping occurs only in August. At mean plant load and mean ambient temperature during August (20.6°C, 69.1°F), the maximum surface temperature in the plume is about 22.1°C (71.8°F). The August lethal threshold would correspond to a 4.4°C (7.9°F) temperature elevation, which is estimated to entrain 5.6m^3/sec of flow, or 0.21% of the ambient low through water body segment I and 0.04% of segment II. Brown trout are being stocked at a rate near 50,000/year. The potentially lethal August exposure would, at worst, crop about 20 of these if all resided in water body segment II.

TABLE VIII-5

MONTHLY AND ANNUAL CROPPING OF ALEWIFE

Month	Temperature °F	Temperature °C	Concentration (#/1000m³)	Lethal Temperature Range °C	Lethal Temperature Elevation °C	Mean Discharge ΔT[1] °C	Entrained Flow m³/sec	Cropping Ratio %
January	36	2.2	ND	ND	>10	8.7	0	0
February	35	1.7	ND	ND	>10	8.7	0	0
March	35	1.7	ND	ND	>10	8.7	0	0
April	37	2.8	4.5477	ND	>10	6.0	0	0
May	42	5.6	1.4039	ND	>10	6.0	0	0
June	54	12.2	4.4574	21.5	~9	6.0	0	0
July	67	19.4	2.5492	23	3.6	9.1	6.5	0.24
August	69	20.6	0.3311	23	2.4	9.1	7.9	0.30
September	65	18.3	0.0446	23	4.7	9.1	5.2	0.19
October	55	12.8	0.0400	21.5	~9	11.1	2.0	0.07
November	46	7.8	ND	ND	10	11.1	~0	~0
December	40	4.4	ND	ND	10	11.1	~0	~0

1In the absence of tempering flow.
ND - no data available.

Coho salmon tolerance data show that the lethal threshold ranges only from 23 to 25°C (73.4 to 77°F) throughout the year. Table VIII-6 lists interpolated thresholds and corresponding temperature elevations for each month. The computed cropping ratio is zero, except during the summer. It averages 0.16% during that three-month period in water body segment I. The annual average is 0.04%. The New York State Department of Environmental Conservation stocked 500,000 young coho in 1974. Coho are not expected to spawn naturally in the lake, hence, a contingency stocking program of comparable magnitude is apparently required. Few coho have been collected near the Oswego site to date; it is expected that the stocked coho will disperse throughout the lake. No quantitative basis for comparison with the calculated cropping ratios is available at this time due to the negligible concentrations of coho observed at Oswego.

Rainbow smelt exhibit an upper lethal threshold of 21.5 to 28.5°C (70.7 to 83.3°F) but no acclimation temperature is specified so that a quantitative assessment is not possible. This threshold, however, is almost always warmer than the surface plume temperature. Therefore, the cropping ratios calculated for other species could be assumed to approximate the ratio for rainbow smelt.

Smallmouth bass lethal thresholds are cited in Appendix A as 35°C (95°F), without a specified acclimation temperature. If it is assumed that this threshold applied at summer ambient temperature, the impact would be zero since the summer discharge temperature is 9.1°C (16.4°F) above the summer ambient of 20.6°C (69.1°F) and, hence, does not reach 35°C (95°F). In all seasons the preferred temperatures of smallmouth bass exceed the discharge temperatures and hence the lethal thresholds do as well. Zero thermal cropping of smallmouth bass is predicted.

Spottail shiners have reported lethal thresholds for spring or fall acclimation temperatures of 30.3°C to 30.8°C (86.5 to 87.4°F). Thermal data for all fish show warmer thresholds in summer than in spring or fall and hence, 30.3°C (65.5°F) may be assumed as a conservatively low threshold for spring, summer, and fall. The plant's discharge temperature rise plus the monthly mean ambient temperature, however, does not exceed 30.3°C (86.5°F) and hence, no cropping is predicted to occur in those seasons.

Threespine stickleback are predicted to have a lethal threshold of about 7°C (12.6°F) above the summer ambient temperatures with an associated cropping ratio of 0.09%. Data are not available to describe any seasonal variability in this rate, hence, this rate is assumed to represent the annual average as well.

White perch data include minimum avoidance temperatures which are below the lethal thresholds. The winter avoidance temperature is 6.6°C

TABLE VIII-6

MONTHLY AND ANNUAL CROPPING OF COHO SALMON

Month	Ambient Temperature °F	Ambient Temperature °C	Lethal Temperature Range °C	Lethal Temperature Elevation °C	Mean Discharge ΔT[1] °C	Entrained Flow m^3/sec	Cropping Ratio %
January	36	2.2	23	21	8.7	0	0
February	35	1.7	23	21	8.7	0	0
March	37	2.8	23	20	6.0	0	0
April	37	2.8	23	20	6.0	0	0
May	42	5.6	23	17	6.0	0	0
June	54	12.2	24	12	6.0	0	0
July	67	19.4	25	5.6	9.1	4.1	0.15
August	69	20.6	25	4.4	9.1	5.6	0.21
September	65	18.3	24.5	6.2	9.1	3.4	0.12
October	55	12.8	24	11.2	11.1	0	0
November	46	7.8	23.5	15.7	11.1	0	0
December	40	4.4	23	19	11.1	0	0

[1]In the absence of tempering flow.

(11.9°F), wherever the summer avoidance temperature is 34.7°C (44.5°F). Treating these as lethal thresholds (which overestimates the impact) and interpolating for various monthly mean ambient temperatures leads to Table VIII-7. The computed cropping ratios for plume entrained flow range from 0.06 to 0.18%. Concentration estimates for the entire year are not available but the information listed implies their presence through the year. The annual average cropping ratio is 0.09%.

Extensive thermal tolerance and preferred temperature data for yellow perch are listed in Appendix A. Table VIII-8 summarizes the lethal temperatures by month. Due to the generally high thresholds, however, only the August cropping estimate is non-zero at 0.05%. Annual average cropping is approximately zero. The concentrations of yellow perch decrease in fall and increase in spring at both Oswego and Nine Mile Point indicating a tendency to move from the area in winter when females require cool water temperature to assure egg development.

The species specific calculation of thermal cropping is a conservative method of estimating the plume impact, since fish exhibit preferenda below lethal temperatures and are, hence, expected to avoid the lethal portion of the plume. Table VIII-9 summarizes the results. Summer is the critical season of cropping of all species except for white perch which are expected to incure increased cropping in winter. The highest cropping ratio is predicted for alewife in August, although their seasonal occurrence in the area reduces the annual rate to an estimated 0.05%, five ten-thousandths of the number entering the segment. Since the impact of Oswego Unit 5 on water body segment I is approximately equal to the impact of all discharges on water body segment II, Table VIII-9 is a description of either impact.

E. CONCLUSIONS

Three alternative interpretations of potential impacts have been quantified in this chapter. They are the plume volume, plume area, and plume entrainment flows. The plume volumes and areas may be considered to be zones which might be removed from viable fish habitation due to temperature elevations of 2° and 3°C (3.6° to 5.4°F). These temperature elevations are conservatively low relative to lethal thresholds of most fish and furthermore fish will generally avoid lethal thresholds. The portions of water body segment I so affected by the Oswego Unit 5 discharge are listed in Table VIII-10. The maximum effect of the 2°C (3.6°F) ΔT isotherm is 0.0034% at capacity operation.

The volumes of the 2°C (3.6°F) are confined to the upper layer of the water column due to the plume buoyancy. The higher concentrations of fish, however, are usually found near the bottom at the site and, hence, the volumes are conservative evaluations of the potential impacts of

TABLE VIII-7

MONTHLY AND ANNUAL CROPPING OF WHITE PERCH

Month	Ambient Temperature (°F)	Ambient Temperature (°C)	Concentration (#/1000 m³)	Lethal Temperature Range (°C)	Lethal Temperature Elevation (°C)	Mean Discharge ΔT (°C)	Entrained Flow (m³/sec)	Cropping Ratio (%)
January	36	2.2	ND	7	5	8.7	4.6	0.17
February	35	1.7	ND	7	5	8.7	4.6	0.17
March	35	1.7	ND	7	5	8.7	4.6	0.17
April	37	2.8	.0360	8	5	6.0	1.8	0.06
May	42	5.6	.0209	12	6	6.0	0	0
June	54	12.2	.0833	18	6	6.0	0	0
July	67	19.4	.0519	28	9	9.1	0	0
August	69	20.6	.0312	30	9	9.1	0	0
September	65	18.3	.0312	27	9	9.1	0	0
October	55	12.8	.0312	20	7	11.1	4.0	0.15
November	46	7.8	ND	14	6	11.1	4.9	0.18
December	40	4.4	ND	10	6	11.1	4.9	0.18

TABLE VIII-8

MONTHLY AND ANNUAL CROPPING OF YELLOW PERCH

Month	Ambient Temperature (°F)	Ambient Temperature (°C)	Concentration (#/1000 m³)	Lethal Temperature Range (°C)	Lethal Temperature Elevation (°C)	Mean Discharge ΔT (°C)	Entrained Flow (m³/sec)	Cropping Ratio (%)
January	36	2.2	ND	21	19	8.7		0
February	35	1.7	ND	21	19	8.7	0	0
March	35	1.7	ND	21	19	8.7	0	0
April	37	2.8	.0020	21	18	6.0	0	0
May	42	5.6	.0035	22	16	6.0	0	0
June	54	12.2	.0208	26	14	6.0	0	0
July	67	19.4	.0209	29	10	9.1	0	0
August	69	20.6	.0106	29	8	9.1	1.3	0.05
September	65	18.3	.0105	28	10	9.1	0	0
October	55	12.8	.0035	26	14	11.1	0	0
November	46	7.8	ND	23	15	11.1	0	0
December	40	4.4	ND	21	17	11.1	0	0

TABLE VIII-9

THERMAL CROPPING IN WATERBODY SEGMENT I

Species	Highest Rate % Month	Highest Rate % Rate	Average %
Alewife	August	0.30	0.05
Brown trout	August	0.21	0.02
Coho Salmon	August	0.21	0.04
Rainbow Smelt	insufficient data		insufficient data
Smallmouth Bass		0	0
Spottail Shiner		0	0
Threespine Stickleback	Summer	0.09	0.09
White perch	Nov-Dec	0.18	0.04
Yellow perch	August	0.05	0

TABLE VIII-10
SUMMARY OF SEGMENT EXCLUSION ZONES

SEASON	LOAD (%)	TEMPERATURE ELEVATION (°C)	VOLUME OF SEGMENT I AFFECTED (%)	CROPPING BY ENTRAINED FLOW BY UNIT 5 FROM SEGMENT I	CROPPING BY ENTRAINED FLOW BY ALL STATIONS FROM SEGMENT II
	Capacity	2	.00341	2.94	1.95
		3	.00039	0.32	0.22
Summer	53.4	2	.00037	0.31	0.33
		3	.00031	0.27	0.28
Fall	70.2	2	.00039	0.33	0.29
		3	.00034	0.29	0.26
Winter	48.7	2	.00037	0.31	0.35
		3	.00031	0.27	0.30
Spring	30.0	2	.00031	0.27	0.41
		3	.00024	0.20	0.31

the plume. The surface area of the plume is also small and in compliance with applicable State thermal criteria.

Table VIII-10 also lists entrained flow into the 2° and 3°C (3.6° to 5.9°F) ΔT isotherms as percentages of the low flow through each water body segment. The percentages represent that portion of the planktonic forms drifting alongshore which may be entrained into the plume. Definitive lethal temperature elevations are not available for most species; but the available data indicate that the evaluation of 2° and 3°C (3.6° to 5.4°F) ΔT isotherms is conservatively low and leads to overestimating the impact of plume entrainment. Plume entrainment amounts to about 0.3% of the segment flow.

The species specific evaluations of possible fish entrainment into the plume are extremely conservative in that fish generally avoid lethal temperatures and the entrainment velocities are too small to entrain fishes. The calculations were performed, however, to illustrate the relative thermal sensitivities of fish in various months. The peak flux cropping so calculated is 0.3% as compared with natural fluctuations by factors of 1.1 (10%) to 8 (800%).

In summary, the plume volumes, areas and entrainment rates are so miniscule relative to the adjacent water body segments that no meaningful impact can be assigned to the Oswego Unit 5 plume or cumulative effects of all three stations in the area. Hence, it is concluded that operation of the Oswego Unit 5 thermal discharge with the requested alternative limitation of 1.03 X 10^9 Kcal/hr (4.10 X 10^9 BTU/hr) will assure the protection and propagation of a balanced indigenous population on the receiving water body, Lake Ontario.

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APPENDIX A

FISH TEMPERATURE DATA SHEETS

FISH TEMPERATURE DATA SHEET

Species: Alewife (Alosa pseudoharengus)

I. Lethal threshold:

	acclimation temperature	larvae	juvenile	adult	data source 3/
Upper	10		2	20	3
	15			23	5
	20			23	3
	Summer			26.7-32.2	6
	Summer		23		3
Lower	17			7	4

II. Growth 1/

	larvae	juvenile	adult	
Optimum and [range 2/]				

III. Reproduction:

	optimum	range	month(s)	
Migration				
Spawning		15.6-27.7		4
		13-16		2
Incubation and hatch		15.5-22 for 6to2 days		1
		17.7		7

IV. Preferred:

acclimation temperature	larvae	juvenile	adult	
Spring			21.2	8

1/ As reported or net growth (growth in wt minus wt of mortality).

2/ As reported or to 50% of optimum if data permit.

3/ Data sources:

1. Rounsefell and Springer, 1945
2. Threiner, 1958
3. Graham, 1956
4. Dept. of Int., 1970
5. Altman and Dittmer, 1966
6. Trembley, 1960 for LD 50
7. Desall, 1970
8. Reutter and Herdendorf, 1974

FISH TEMPERATURE DATA SHEET

Species: Brown trout (Salmo trutta)

I. Lethal threshold:

	acclimation temperature	larvae	juvenile	adult	data source 3/
Upper				23.5	5
	14-18			25	3
Lower					

II. Growth 1/

	larvae	juvenile	adult	
Optimum and			18.3-23.9	2
[range 2/]			8-17	4
			12	6
			12.4-17.6	7

III. Reproduction:

	optimum	range	month(s)	
Migration				
Spawning		6.7-8.9	Oct-Nov	1
Incubation and hatch	7.3 for 64 days 10.0 for 41 days			8

IV. Preferred:

acclimation temperature	larvae	juvenile	adult	

1/ As reported or net growth (growth in wt minus wt of mortality).
2/ As reported or to 50% of optimum if data permit.
3/ Data sources:

1. Mansell, 1965
2. Brynildson et al., 1963
3. Klein, 1962
4. Brett, 1970
5. Bishai, 1960
6. Swift, 1961
7. Ferguson, 1958
8. Bardech et al., 1972

FISH TEMPERATURE DATA SHEET

Species: Coho salmon, (Oncorhynchus kisutch)

I. Lethal threshold:

	acclimation temperature	larvae	juvenile	adult	data source 3/
Upper	5		23		1
	10		24	21*(3)	1,3
	15		24		1
	20		25		1
	23		25		1

*Acclimation temp. unknown

	acclimation temperature	larvae	juvenile	adult	data source 3/
Lower	5		0.2		1
	10		2		1
	15		3		1
	20		5		1
	23		6		1

II. Growth 1/

	larvae	juvenile	adult	
Optimum and		15*		2
[range 2/]		(5-17)		6

*unlimited food

III. Reproduction:	optimum	range	month(s)	
Migration		7-16(5)		5
Spawning		7-13(3)	Fall	3
Incubation and hatch			Winter-Spring	

IV. Preferred:

acclimation temperature	larvae	juvenile	adult	
Winter			13	4
Spring		11.4		7

1/ As reported or net growth (growth in wt minus wt of mortality).
2/ As reported or to 50% of optimum if data permit.
3/ Data sources:

1. Brett, 1952
2. Great Lakes Research Labortory, 1973
3. Anonymous, 1971
4. Edsall, 1970
5. Burrows, 1963
6. Averett, 1968
7. Reutter and Herdendorf, 1974

FISH TEMPERATURE DATA SHEET

Species: Rainbow smelt (Osmerus mordax)

I. Lethal threshold:	acclimation temperature	larvae	juvenile	adult	data source 3/
Upper				21.5-28.5	1
Lower					

II. Growth 1/	larvae	juvenile	adult	
Optimum and				
[range 2/]				

III. Reproduction:	optimum	range	month(s)	
Migration			March-April	5
Spawning	8.9			2
Incubation		11-15	June	4
and hatch		6-10 for 29 to 19 days		3

IV. Preferred:	acclimation temperature	larvae	juvenile	adult	
				7.2	6

1/ As reported or net growth (growth in wt minus wt of mortality).
2/ As reported or to 50% of optimum if data permit.
3/ Data sources:

1. Altman and Dittmer, 1966
2. Scott and Crossman, 1973
3. McKenzie, 1964
4. Sheri and Power, 1968
5. QLM, 1974 Nine Mile Study
6. Hart and Ferguson, 1966

FISH TEMPERATURE DATA SHEET

Species: Smallmouth bass, (Micropterus dolomieui)

I. Lethal threshold:	acclimation temperature	larvae	juvenile	adult	data 3/ source
Upper		38* (9)	35 (3)		9, 3
		*acclimation not given			
Lower	15(3)	4(9)*	2(3)		3, 9
	18		4		3
	22		7		3
	26		10		3
		*acclimation temperature not given			

II. Growth 1/	larvae	juvenile	adult	
Optimum and	28-29(2)	26 (3)		2, 3
[range 2/]				

III. Reproduction:	optimum	range	month(s)	
Migration				
Spawning	17-18(5)	13(8)-21(7)	May-July(8)	5, 7, 8
	16.1-18.3	12.8-20.0		12
Incubation and hatch			May-July	

IV. Preferred:	acclimation temperature	larvae	juvenile	adult	
	Summer			21-27	6
	Winter			>8*(1)-28(4)	1, 4
	21			20.3-21.3	10
				20-30**	11
	Winter		18.0	12-13	13
	Spring		19-24	15-16	13
	Summer		31.0	30.0	13
	Fall		24-27	21-23	13
	Fall			26.6	14

*Life stage unknown
**Avoidance

FISH TEMPERATURE DATA SHEET

Species: Smallmouth bass, (Micropterus dolomieui)(Continued)

1/ As reported or net growth (growth in wt minus wt of mortality).
2/ As reported or to 50% of optimum if data permit.
3/ Data sources:

1. Munther, 1968.
2. Peek, 1965.
3. Morning and Pearson, 1973.
4. Fergusen, 1958.
5. Breder and Rosen, 1966
6. Emig, 1966.
7. Hubbs and Baily, 1938.
8. Surber, 1942
9. Larimore and Duever, 1968
10. Ferguson, 1958
11. Cherry, et al., 1975
12. Scott and Crossman, 1973
13. Barans and Tubb, 1973
14. Reutter and Herdendorf 1974

FISH TEMPERATURE DATA SHEET

Species: Spottail shiner (Notropis hudsonius)

I. Lethal threshold:	acclimation temperature	larvae	juvenile	adult	data source[3/]
Upper	11			30.8	1
	7			30.3	1
Lower					

II. Growth [1/]	larvae	juvenile	adult	
Optimum and [range[2/]]				

III. Reproduction:	optimum	range	month(s)	
Migration				
Spawning	20			3,4
Incubation and hatch				

IV. Preferred:	acclimation temperature	larvae	juvenile	adult	
				14	2
	Winter			10.2	5
	Spring			14.5	5

1/ As reported or net growth (growth in wt minus wt of mortality).
2/ As reported or to 50% of optimum if data permit.
3/ Data sources:

1. Trembley, 1961, LD 50
2. Meldrim and Gift, 1971
3. Peer, 1961
4. Carlander, 1969
5. Reutter and Herdendorf, 1974

FISH TEMPERATURE DATA SHEET

Species: Threespine stickleback (Gasterosteus aculeatus)

I. Lethal threshold

	acclimation temperature	larvae	juvenile	adult	data source[3]
Upper	19			25.8	1
	20			27.2	2
				31.7-33	3
Lower					

II. Growth[1]

	larvae	juvenile	adult	
Optimum and				
[range[2]]			< 37.1	3

III. Reproduction:

	optimum	range	month(s)	
Migration				
Spawning				
Incubation and hatch		19 for 7 days		4

IV. Preferred:

acclimation temperature	larvae	juvenile	adult	

1/ As reported or net growth (growth in wt minus wt of mortality).
2/ As reported or to 50% of optimum if data permit.
3/ Data sources:

1. Blahm and Parente, 1970
2. Jordan and Garside, 1972
3. Altman and Pittner, 1966
4. Breder and Rosen, 1966

FISH TEMPERATURE DATA SHEET

Species: White perch (Morone americana)

I. Lethal threshold:

	acclimation temperature	larvae	juvenile	adult	data source 3/
Upper	1.1			6.6	2
	24.8			34.7	2
Lower					

II. Growth 1/

	larvae	juvenile	adult	
Optimum and			23.9	1
[range 2/]				

III. Reproduction:

	optimum	range	month(s)	
Migration				
Spawning		11-15	May-June	4
Incubation and hatch		15-20 for 4.5-1.2 days		3

IV. Preferred:

acclimation temperature	larvae	juvenile	adult	

1/ As reported or net growth (growth in wt minus wt of mortality).
2/ As reported or to 50% of optimum if data permit.
3/ Data sources:

1. Meldrim and Gift, 1971
2. Meldrim and Gift, 1971, minimum avoidance temperature
3. Scott and Crossman, 1973
4. Sheri and Power, 1968

FISH TEMPERATURE DATA SHEET

Species: Yellow perch (Perca flavescens)

I. Lethal threshold:

	acclimation temperature	larvae	juvenile	adult	data source 3/
Upper	5			21.3	1
	9-18			13-22	12
	10			25	1
	22-24			29-30	2
	25			29.7	3,1
Lower	25		4		1

II. Growth 1/

	larvae	juvenile	adult	
Optimum and				
[range 2/]			13-20	5,6

III. Reproduction:

	optimum	range	month(s)	
Migration				
Spawning	12(11)	7.2-12.8 (9)		9, 11
Incubation and hatch		5-10 (10)	March-June (11)	10, 11

IV. Preferred:

acclimation temperature	larvae	juvenile	adult	
			21-24	4
			19.7 (field)	4
10		19.3	17.0	4
15		23.0	20.0	4
20		23.1	20.5	4
			10-29	7
24		20		8
Winter		10-13	7-12	13
Winter			14.1	14
Spring		18.0	13-16	13
Summer		25-27	27.0	13
Summer			20.9	14
Fall		28.0	22-25	13
Fall			19.9	14

1/ As reported or net growth (growth in wt minus wt of mortality).
2/ As reported or to 50% of optimum if data permit.
3/ Data sources:

FISH TEMPERATURE DATA SHEET

Species: Yellow perch (*Perca flavescens*) (Continued)

1. Hart, 1947
2. Black, 1953
3. Brett, 1956
4. Ferguson, 1958
5. Cobble, 1966
6. Weatherly, 1963
7. Barans and Tubb, 1973
8. McCauley, 1973
9. Breder and Rosen, 1966
10. QLM, 1974 Nine Mile Study
11. Jones, et al., 1973
12. Everest, 1973
13. Barans and Tubb, 1973
14. Reutter and Herdendorf, 1974

FISH TEMPERATURE DATA SHEET

Species: Gammarus fasciatus (Amphipoda)

I. Lethal threshold:	acclimation temperature	larvae	juvenile	adult	data source [3/]
Upper	2.5°C			28°C*	1
	11°C			31°C*	1
	19.8°C			34°C	1
	25°C 4/			37°C*	1
Lower	* 30 minute TLm for Gammarus sp. in Hudson				

II. Growth [1/]		larvae	juvenile	adult	
Optimum and [range [2/]]	interval between moults		6-11 days (18°C)	8-15 days (21°C)	
			4-11 days (21°C)		2
			3-6 days (25°C)		

III. Reproduction:	optimum	range [5/]	
Spawning	Summer	lower limit = 10°C(fall)	2
		lower limit = 4°C(spring)	
Incubation and hatch	7 days at 24°C; 9 days at 20°C; 14 days at 18°C; 22 days at 15°C		2

IV. Preferred:	acclimation temperature	larvae	juvenile	adult	
	prefers cool waters				3

1/ As reported or net growth (growth in wt minus wt of mortality).
2/ As reported or to 50% of optimum if data permit.
3/ Data sources: (see attached)
4/ Twenty-four hour latent mortality was observed following 30 minute and 60 minute elevated temperature exposures. Gammarus sp. acclimated at 25°C suffered no mortality when exposed to 35°C for 1 hour; when exposed to 37°C for 1 hour 92% of Gammarus sp. died within 24 hours.
5/ Reproduction at 30°C

FISH TEMPERATURE DATA SHEET

Species: Gammarus fasciatus (Amphipoda) (Continued)

1. Lauer, G.J., W.T. Waller, D.W. Bath, W. Meeks, R. Heffner, T. Ginn, L. Zubarik, P. Bibko and P. Storm. 1974.
2. Clemens, H.P. 1950.
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4. Embody, G.C. 1912.

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