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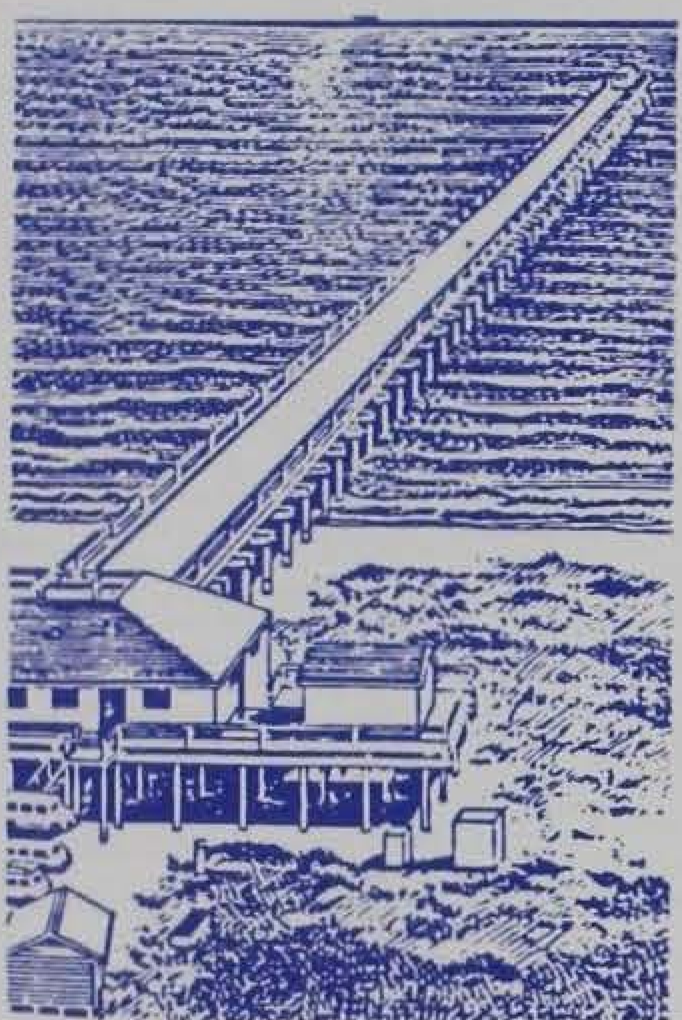

TECHNICAL REPORT CERC-90-3

CURRENT AND TEMPERATURE EFFECTS AT EIGHTEENMILE CREEK AS A RESULT OF HARBOR IMPROVEMENTS AT OLCOTT HARBOR, NEW YORK

Hydraulic Model Investigation

by

Robert R. Bottin, Jr.

Coastal Engineering Research Center

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A 1:60-scale (undistorted) hydraulic model of Olcott Harbor, NY, was used to determine the effects of proposed improvements on creek temperatures and currents at Eighteenmile Creek as they entered Lake Ontario. The model (originally used to develop the optimum improvements) reproduced approximately 3,300 and 3,600 ft of the New York shoreline on the east and west sides of the harbor, respectively, about 3,000 ft of the lower reaches of Eighteenmile Creek, and sufficient offshore bathymetry in Lake Ontario to permit generation of the required test waves. Improvements consisted of the installation of rubble-mound breakwaters and channel dredging. An 80-ft-long unidirectional, spectral wave generator and a reservoir of heated water were utilized in model operation. Prototype data were obtained at Eighteenmile Creek during the spring and fall seasons of 1989. Tests then were conducted to verify the performance of the model for existing conditions, and finally, the improvement plan was tested to determine its impact on temperature and current patterns. It was concluded that trends in
(Continued)

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the model (temperatures, direction of creek plume, etc.) followed trends established in the prototype for existing conditions. With the improvement plan installed, the creek currents and temperature differences varied only slightly in the localized area of the creek mouth, and, on a regional basis, the movement of creek currents after entering the lake was similar to existing conditions. Test results, in general, indicated that the improvement plan will have minimal effects on temperatures and/or the movement of creek water into the lake or along the shorelines.

PREFACE

A request for current and temperature effects testing of Eighteenmile Creek at Olcott Harbor, New York, was initiated by the US Army Engineer Division, North Central (NCD). Authorization for the US Army Engineer Waterways Experiment Station (WES) to perform the study was subsequently granted and funds were authorized by the US Army Engineer District, Buffalo, on 13 April 1989.

Model testing was conducted at WES during the period September to November 1989 by personnel of the Wave Processes Branch (WPB), Wave Dynamics Division (WDD), Coastal Engineering Research Center (CERC) under the direction of Dr. J. R. Houston, Chief, CERC; Mr. C. C. Calhoun, Jr., Assistant Chief, CERC; Mr. C. E. Chatham, Jr., Chief, WDD; and Mr. D. G. Outlaw, Chief, WPB. The tests were conducted by Mr. H. F. Acuff, Civil Engineering Technician, WPB, under the supervision of Mr. R. R. Bottin, Jr., Physical Scientist, WPB. This report was prepared by Mr. Bottin.

During the course of the investigation, liaison was maintained by means of conferences, telephone communications, and monthly progress reports. Mr. Charlie Johnson, NCD, visited WES to observe model operation during the course of the study.

Initial test results for the model that investigated wave, current, creek flood flow conditions, and sediment patterns for the existing harbor and various improvement plans were reported in WES Technical Report CERC-90-1, "Olcott Harbor, New York, Design for Harbor Improvements; Coastal Model Investigation," dated February 1990. Test results determining the impacts of the improvement plan on creek currents and temperature conditions at Eighteenmile Creek are reported herein.

COL Larry B. Fulton, EN, is Commander and Director of WES. Dr. Robert W. Whalin is Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4046.856	square metres
cubic feet	0.02831685	cubic metres
degrees (angle)	0.01745329	radians
feet	0.3048	metres
inches	25.4	millimetres
miles (US statute)	1.609347	kilometres
pounds (force)	4.448222	newtons
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic feet	16.01846	kilograms per cubic metre
slugs (mass) per cubic feet	515.3788	kilograms per cubic metre
square feet	0.09290304	square metres
square miles (US statute)	2.589988	square kilometres

CURRENT AND TEMPERATURE EFFECTS AT EIGHTEENMILE

CREEK AS A RESULT OF HARBOR IMPROVEMENTS

AT OLCOTT HARBOR, NEW YORK

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. Olcott Harbor is located on the southern shore of Lake Ontario (Figure 1) at the mouth of Eighteenmile Creek. It is a small hamlet in Niagara County in the town of Newfane, NY, situated about 18 miles* east of the mouth of the Niagara River. Eighteenmile Creek is about 14 miles long and drains an area of approximately 85 sq miles. An inactive power dam (Burt Dam), located about 2 miles upstream, regulates to some degree the flow conditions in the lower reaches of the creek. The dam also traps sediments, and therefore, sedimentation in the stream below the dam is relatively low in comparison to other harbors maintained by the Corps of Engineers at the mouth of rivers and creeks (US Army Engineer District, Buffalo, 1978).

2. The existing Federal project for Olcott Harbor was authorized by the River and Harbor Act of 1913 and provides for parallel jetties at the creek mouth located 200 ft apart (Figure 2). The east and west jetties are 850 and 873 ft long with crest elevations (el)** of 6 and 7 ft, respectively. They are concrete capped, vertical, steel sheet-pile structures. The project also includes a 12-ft-deep, 140-ft-wide entrance channel extending lakeward from the shoreward ends of the jetties to the -12 ft contour in Lake Ontario. A case history of the jetty structures at Olcott Harbor may be obtained from (Bottin 1988).

3. Olcott Harbor has been fully developed with boat docks and facilities on both banks of the Creek. The harbor has a mooring capacity of 134 vessels and can accommodate boats ranging up to 68 ft in length. Major

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* A table of factors for converting non-SI units of measurement to SI (metric) units are presented on page 3.

** All elevations (el) cited herein are in feet referred to low water datum (lwd). Low water datum on Lake Ontario is 242.8 ft above International Great Lakes Datum (IGLD) of 1955.

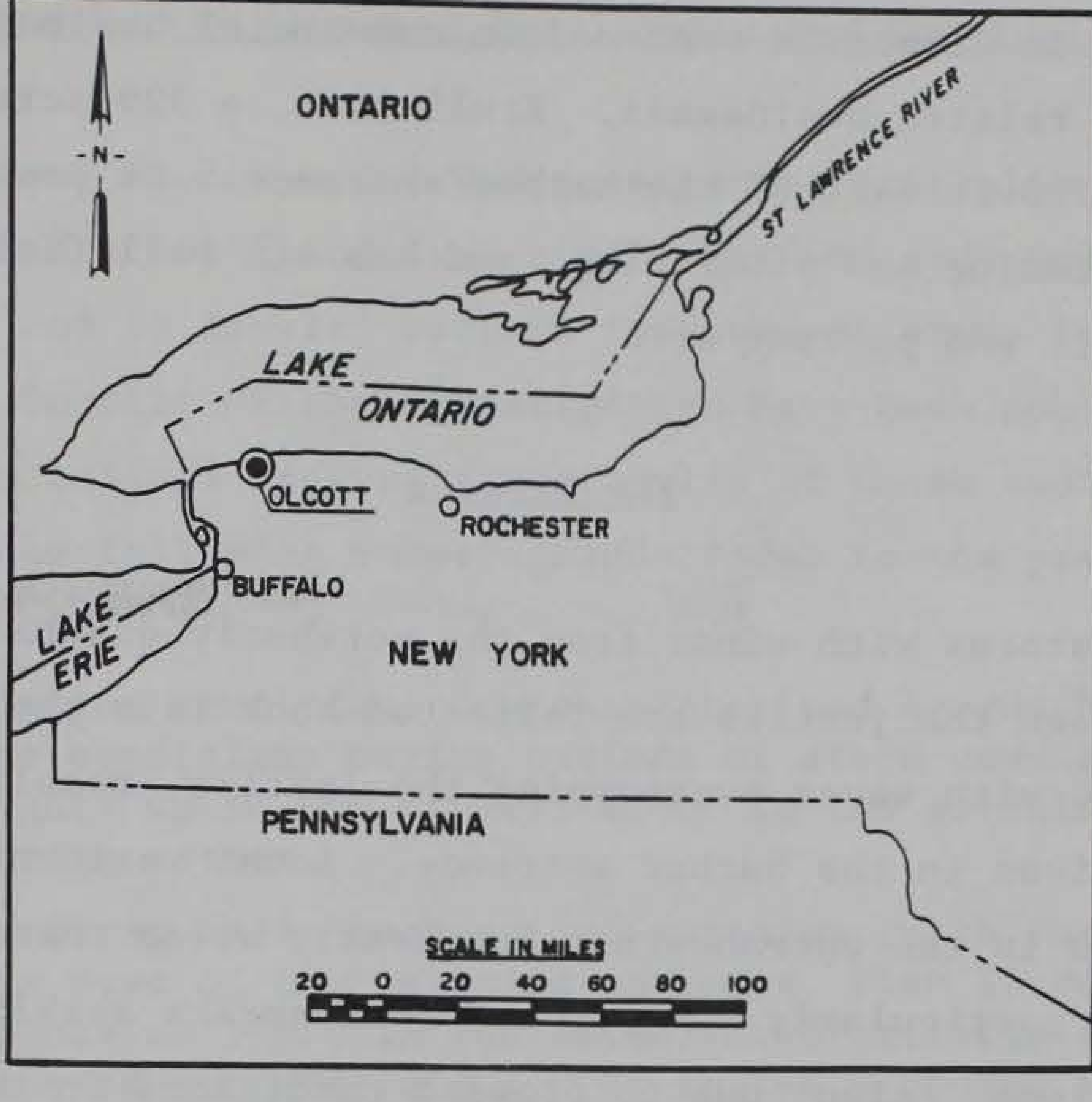

Figure 1. Project location

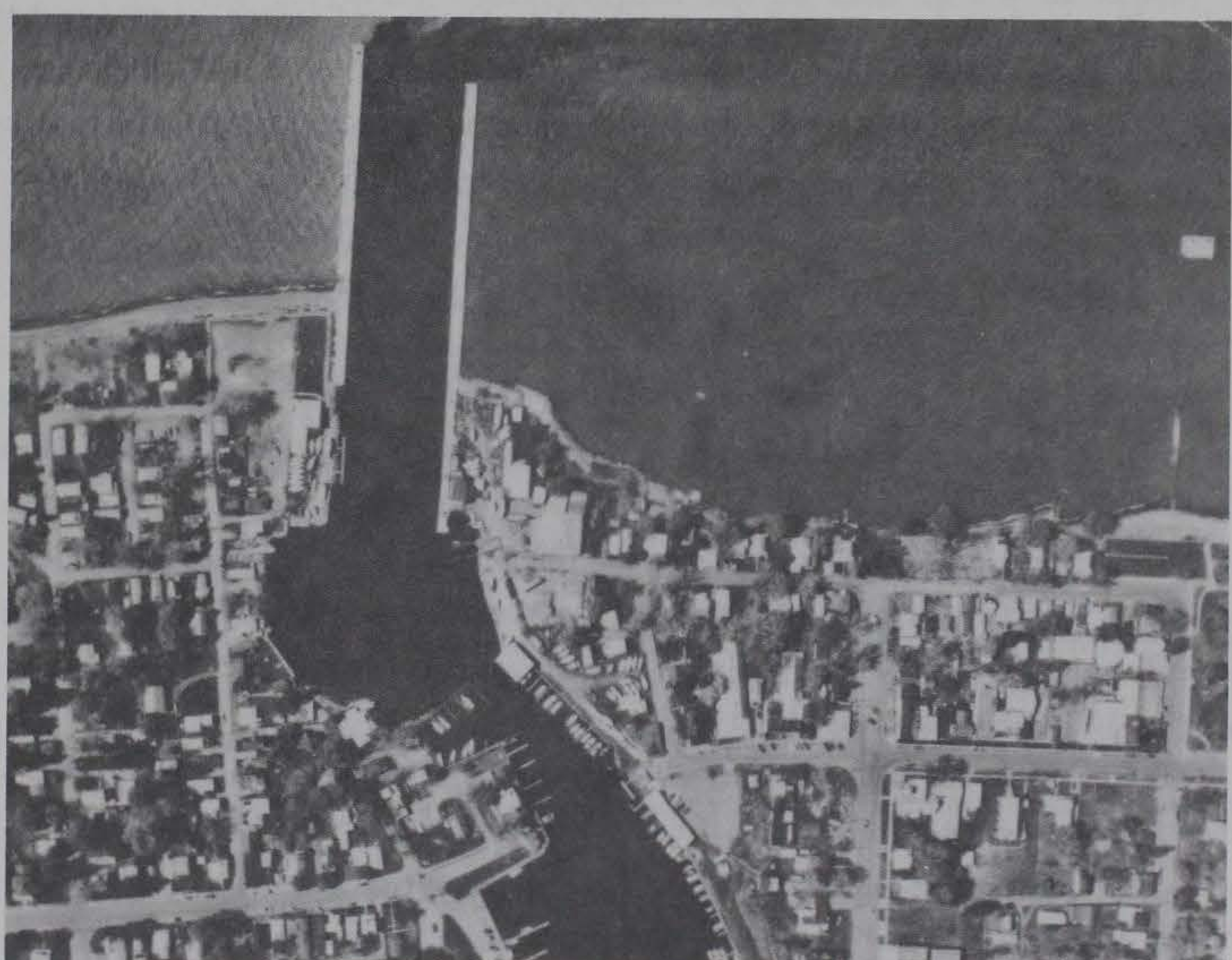

Figure 2. Aerial view of harbor

economic activity in Olcott is centered in commercial business enterprises, especially marine-related businesses. Krull Park, a 329-acre county park, is situated about 1,300 ft east of the harbor entrance. It provides recreational facilities for swimming and picnicking, and has six ball fields, a field house, wading pool, and parking area.

The Problem

4. During storms with winds from the northerly quadrant, waves entering the entrance between the jetties are reflected back into the channel. This situation combined with waves overtopping the jetties, results in extremely rough wave conditions in the harbor entrance. Local residents report that boating conditions in the entrance are frequently worse than in the open-lake. This situation is particularly dangerous for strangers seeking refuge during storm wave conditions. Also, due to crowded conditions in the harbor, visiting craft have difficulty in finding mooring space.

5. The harbor is exposed to northerly storms and waves entering between the jetties which have caused vessels to break loose from their moorings resulting in damages to themselves and other boats against which they strike. Harbor facilities also have been damaged. Damages from individual storms have reached over $20,000 (US Army Engineer District, Buffalo, 1978).

6. Submerged remains of a bridge pier in midstream of the harbor restricts free and easy navigation upstream. A shallow, poorly defined, irregular, natural channel with navigable widths limited to 10 ft in places also causes navigational difficulties to boat owners in the area. The development of additional berthing facilities on the creek banks upstream is restricted due to these navigational hazards. A regional analysis of boating needs on Lake Ontario and in Niagara County indicates an immediate need for more than 500 additional berths for permanently based vessels at Olcott Harbor and a demand for 300 more moorings by 1996.

7. In summary, improvements are needed at Olcott Harbor to provide safe entrance channel conditions and protected mooring facilities during attack by storm waves. Harbor modifications would also provide a harbor-of-refuge for small boats caught in the open-lake during storms, and alleviate crowded conditions by providing additional berths to accommodate the high and growing demand for such facilities in the area.

Previously Reported Model Tests and Conclusions

8. The Olcott Harbor model was constructed initially to investigate waves, current, and creek flood flow conditions and sediment patterns for the existing harbor, and to develop optimum improvement plans for two basic harbor configurations. Details of the investigation have been published (Bottin and Acuff 1990). Conclusions derived from results of these tests are shown below. Plan numbers in the following subparagraphs refer to the previous investigation.

a. Existing conditions are characterized by rough and turbulent wave conditions during periods of storm wave attack. Wave heights up to 6.5 ft will occur in the existing entrance during boating season.

b. The first basic harbor configuration (with the proposed mooring area east of the existing entrance, Plan 1) resulted in wave heights well within the established criteria (3.0 ft in the proposed entrance and 1.0 ft in the proposed mooring area) for boating season wave conditions.

c. The following modifications may be made to the detached breakwater of the first harbor configuration and acceptable boating season wave conditions will be achieved.

(1) The east and west detached breakwaters may be reduced in el from +16.2 ft and +15.3 ft, respectively, to +14.5 ft.

(2) The length of the east breakwater may be reduced by 125 ft (removal from the shoreward end of the structure).

(3) The length of the west breakwater may be reduced by 350 ft (removal of 50 ft from the lakeward end and 300 ft from the shoreward end of the structure).

d. Based on test results, the detached east and west breakwaters of the second basic harbor configuration were reduced to els of +14.5 ft and the east breakwater length was reduced by 125 ft (paragraphs c1 and 2). In addition, 50 ft may be removed from the shoreward end of the west breakwater (Plan 19) and acceptable wave conditions during boating season will be achieved for the second harbor configuration (mooring areas east and west of the existing entrance).

e. The openings between the attached and detached east and west breakwaters of the second basic harbor configuration will provide wave-induced current flow through the harbor and should enhance circulation.

f. The construction of the proposed harbor plan will have minimal impact on water surface elevations and creek current velocities in the lower reaches of Eighteenmile Creek.

g. The opening between the attached and detached west breakwater (Plan 19) may result in minor shoaling in the mooring area in the western portion of the harbor for test waves from 313 and 334 degrees, provided a sediment source is available. The installation of a sill between the structures (Plan 21), an extension of the attached breakwater (Plan 22), or a spur on the attached structure (Plan 23) will alleviate this shoaling.

h. Sediment placed between the existing groins east of the harbor for Plan 19 moves easterly and westerly between the structures, but will remain relatively stable and not move from one cell to another. Accumulations may occur on the western sides of each cell, however, due to the predominance of the wave directions attacking the groin field.

Model views of the optimum plans for the first and second basic harbor configurations are shown in Photos 1 and 2.

Purpose of the Current Investigation

9. At the request of the US Army Engineer District, Buffalo (NCB), the hydraulic model of Olcott Harbor was utilized by the US Army Engineer Waterways Experiment Station's (WES) Coastal Engineering Research Center (CERC) to (a) determine if the model could accurately reproduce prototype current patterns and temperature conditions as creek currents moved into the Lake, and (b) determine the impact of the proposed improvements on current patterns and temperature conditions as creek currents moved into the Lake. As indicated in paragraph 8, two basic harbor configurations were developed in the previous investigation (Photos 1 and 2). Due to time and cost constraints for this portion of the investigation, only one harbor configuration was selected for testing. Since the second basic harbor configuration (mooring areas east and west of the existing entrance) enclosed the existing entrance with more or longer breakwater structures, it was determined this configuration would have more impact on creek currents and temperature conditions than the first basic configuration (mooring area east of the existing entrance). The logic was that if the second configuration resulted in satisfactory conditions, then conditions for the first harbor configuration would be as good or better. Therefore, the second basic harbor configuration developed in the previous investigation was selected for model testing.

PART II: THE MODEL

Design of Model

10. The Olcott Harbor model (Figure 3) was constructed to an undistorted linear scale of 1:60, model to prototype. Scale selection was based on such factors as:

- a. Depth of water required in the model to prevent excessive bottom friction.
- b. Absolute size of model waves.
- c. Available shelter dimensions and area required for model construction.
- d. Efficiency of model operation.
- e. Available wave-generating and wave-measuring equipment.
- f. Model construction costs.

A geometrically undistorted model was necessary to ensure accurate reproduction of short-period wave and current patterns. Following selection of the linear scale, the model was designed and operated in accordance with Froude's model law (Stevens 1942). The scale relations used for design and operation of the model were as follows:

Characteristic	Dimension*	Scale Relations Model:Prototype
Length	L	$L_r = 1:60$
Area	L^2	$A_r = L_r^2 = 1:3,600$
Volume	L^3	$\forall_r = L_r^3 = 1:216,000$
Time	T	$T_r = L_r^{1/2} = 1:7.75$
Velocity	L/T	$V_r = L_r^{1/2} = 1:7.75$
Roughness (Manning's coefficient, n)	$L^{1/6}$	$n_r = L_r^{1/6} = 1:1.979$
Discharge	L^3/T	$Q_r = L_r^{5/2} = 1:27,885$

* Dimensions are in terms of length and time.

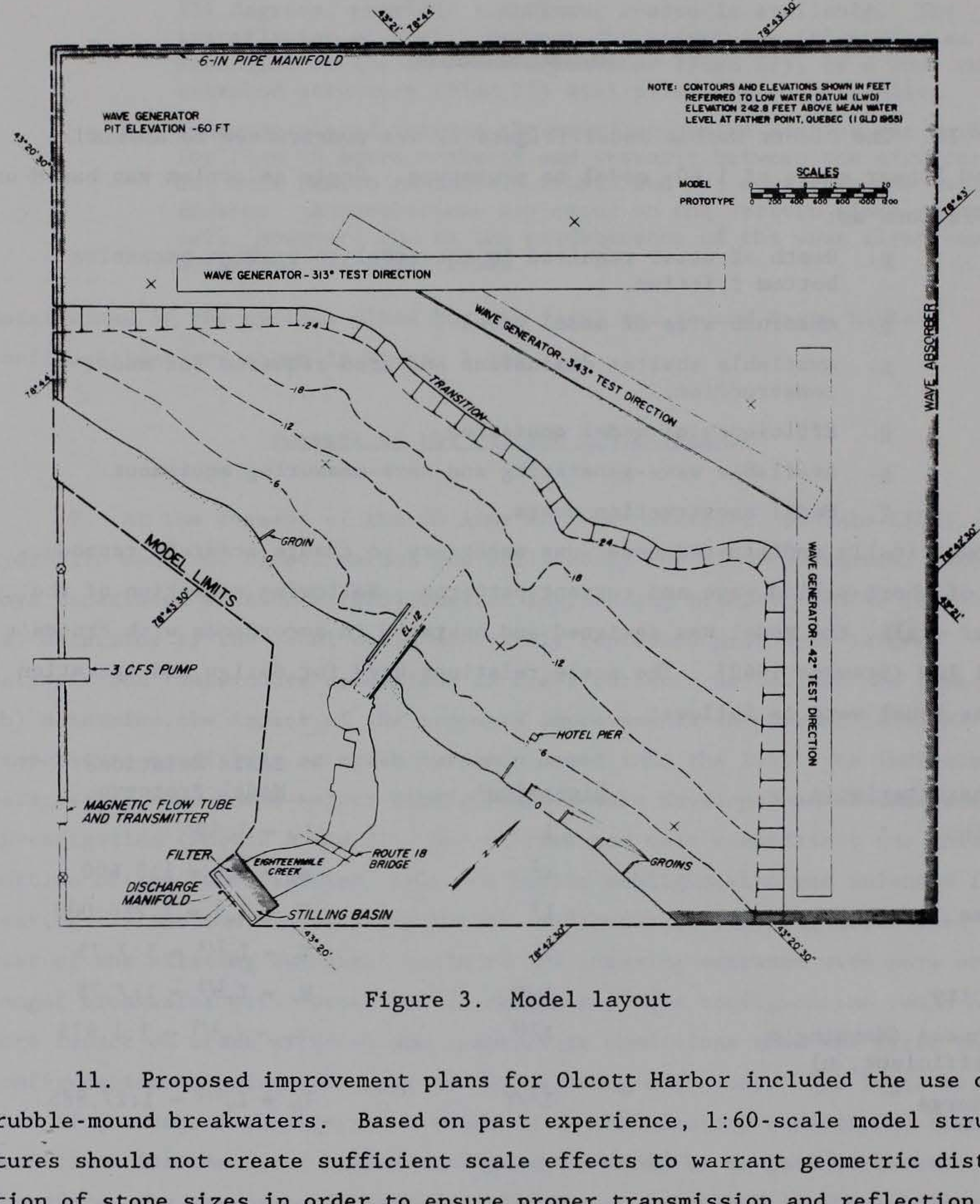

Figure 3. Model layout

11. Proposed improvement plans for Olcott Harbor included the use of rubble-mound breakwaters. Based on past experience, 1:60-scale model structures should not create sufficient scale effects to warrant geometric distortion of stone sizes in order to ensure proper transmission and reflection of wave energy. Therefore, rock size selection was based on linear scale relations and specific weight of 155 lb/ft^3 for the prototype stone.

12. The values of Manning's roughness coefficient (n) used in the design of the improved creek channel were calculated from water surface profiles of known discharges in the prototype. From these computations and

experience, an n value of 0.030 was selected for use in the main creek channel. In addition, based on experience, n values of 0.060, in areas where existing depths were greater than 1.0 ft and 0.080, in areas where existing depths were less than 1 ft, were selected for use in the creek. Therefore, based on previous WES investigation (Miller and Peterson 1953, and Cox 1973), the various model areas in Eighteenmile Creek were given finishes that would represent prototype n values of 0.030, 0.060, and 0.080.

The Model and Appurtenances

13. The model reproduced approximately 7,000 ft of the New York shoreline and included the existing harbor entrance and the lower 3,000 ft of Eighteenmile Creek. Underwater bathymetry also were reproduced in Lake Ontario to an offshore depth of -24 ft with a sloping transition to the wave generator pit el of -60 ft. The total area reproduced in the model was approximately 13,930 sq ft, representing about 1.8 sq miles in the prototype. A general view of the model is shown in Figure 4. Vertical control for model construction was based on low water datum (lwd), el 242.8 ft above mean water

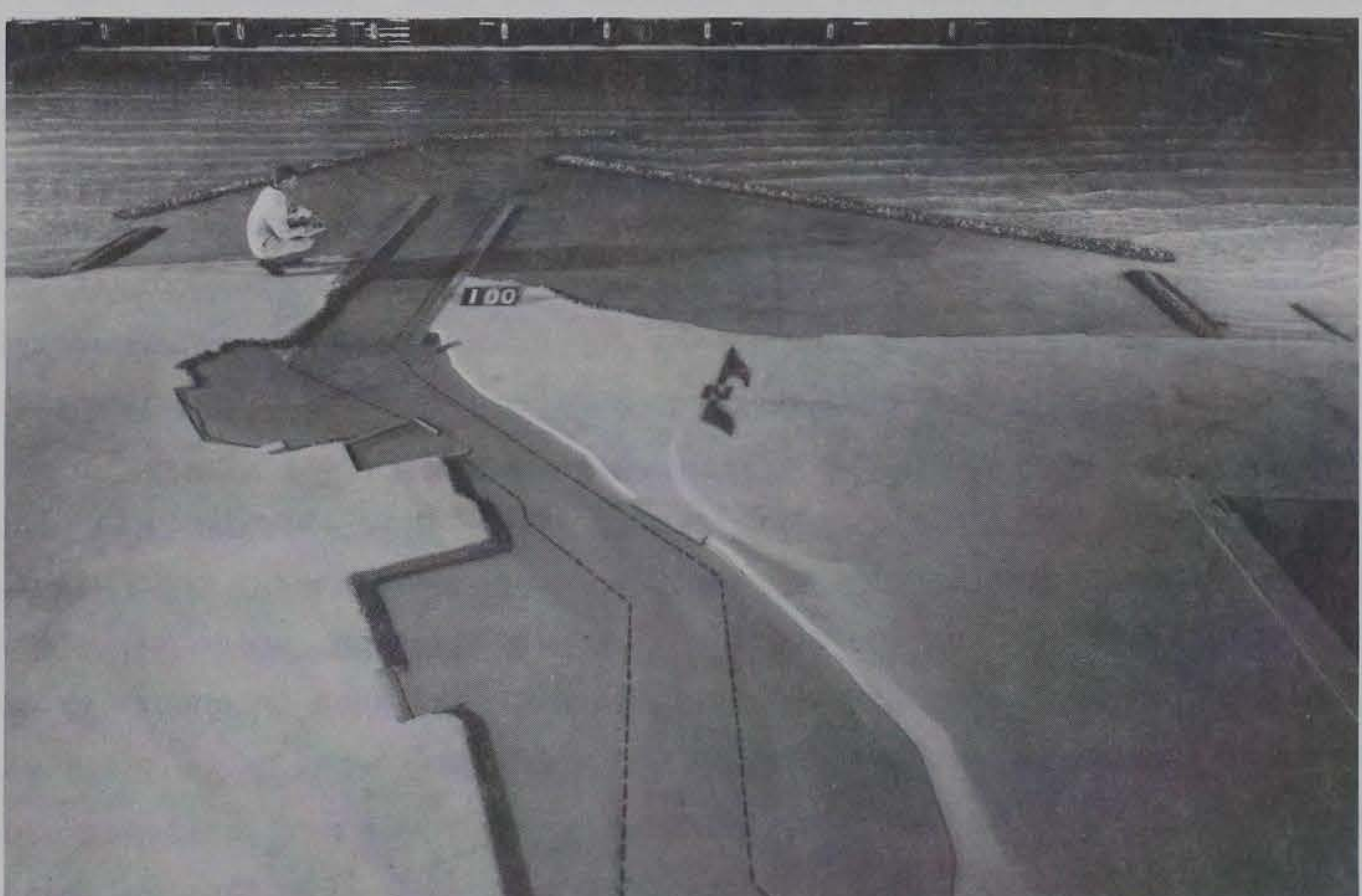

Figure 4. General view of model

level at Father Point, Quebec (IGLD of 1955). Horizontal control was referenced to a local prototype grid system.

14. Model waves were generated by an 80-ft-long, unidirectional spectral wave generator with a trapezoidal-shaped, vertical-motion plunger. The electrohydraulic wave generator utilized a hydraulic power supply. The vertical motion of the plunger was controlled by a computer-generated command signal, and the movement of the plunger caused a periodic displacement of water which generated the required test waves. The wave generator also was mounted on retractable casters which enabled it to be positioned to generate waves from the required directions.

15. A water circulation system (Figure 3) consisting of a 6-in, perforated-pipe water-intake manifold, a 3-cfs pump, and a magnetic flow tube and transmitter, was used in the model to reproduce steady-state flows through the creek channel and harbor area that corresponded to selected prototype creek discharges.

16. A reservoir of heated water was used to determine temperature conditions in the model. The heated water was introduced into the creek to represent discharges for the spring and fall seasons. It was also dyed so that current patterns could be traced as the creek discharges entered the lake where they were impacted by the wave climate and moved further into the lake and/or along the shorelines.

17. Temperatures at various locations in the model were recorded with thermistor probes during the conduct of the tests. These probes are precision temperature sensing devices that were used with a thermometer recorder. Thermistors respond rapidly to the slight temperature change and accurately measure electrical resistance which gives a direct reading of the precise temperature at a given location.

18. A 2-ft (horizontal) solid layer of fiber wave absorber was placed around the inside perimeter of the model to dampen wave energy that might otherwise be reflected from the model walls. In addition, guide vanes were placed along the wave generator sides in the flat pit area to ensure proper formation of the wave train incident to the model contours.

PART III: PROTOTYPE DATA AND TEST CONDITIONS

Prototype Survey Data

Station locations and data

19. Prototype temperature and current data were obtained at four stations in the lower reaches of the creek (below Burt dam) and one station in the Lake. Station locations were approximately the same for each survey. They were relocated after the initial survey by observation of lakeshore landmarks/shoreline features or, in the stream, stream bank features. Station locations are shown in Plate 1. The data were collected by the Fish and Wildlife Service. In addition to temperatures and currents, other survey data including weather conditions, time of observation, estimated wave heights, and fisheries data were obtained. Data utilized for the physical model tests included currents, temperature, and estimated wave heights. Survey data were obtained for the spring (surveys 1-6) and fall (surveys 7-12) seasons. Dates for the two survey series are presented in Table 1.

Spring survey data

20. Temperature data for stations 1-5 for the spring survey series are shown in Plates 2-6 for the various depths. The stations in the creek (stations 2-5) showed a gradual warming trend for surveys 1 and 3-6. Survey 2 followed a late spring snow in the region and resulted in lower temperatures in the creek than normal due to the snow melt. Generally, surface temperatures were slightly higher than temperatures obtained below the surface, however, the variation from surface to bottom is relatively small. Depth-averaged temperatures at stations 1-5 for the various surveys are shown in Plate 7. Trends indicate the averaged lake temperature is cooler than the creek temperature, except for survey 2, due to the late snowfall. Data also indicate that temperatures at station 2 (located between the jetties) is influenced by the cooler lake water.

21. Velocity data obtained at station 5 were used to calculate the creek discharge for each survey. This station was selected due to its more remote location from the lake, straighter approach channel in the vicinity of the station, and well defined channel. Flooding of shallow water areas adjacent to the channel at stations 3 and 4 could drastically increase the channel cross-section. The channel cross section was adjusted for the lake elevation

for each survey. Velocity data were averaged at station 5 for surveys 1,2,3,5 and 6. For survey 4, sufficient data were not available to determine discharge. The discharge data is shown in Plate 8 and it ranged from 120 to 280 cfs with the exception of survey 2, which was 830 cfs due to runoff from the snow melt.

Fall survey data

22. Temperature data for stations 1-5 for the fall survey series are shown in Plates 9-13 for the various depths. All stations showed a gradual cooling trend for surveys 7-12. Generally, surface temperatures were similar to those below the surface with few exceptions. Depth-averaged temperatures at stations 1-5 for the various fall surveys are presented in Plate 14. The temperature of the water in the creek is much closer to the temperature of the water in the lake (as opposed to the spring surveys). Malfunction in temperature gages in the prototype resulted in an absence of data in the plots on Plates 9-14.

23. Velocity data secured at station 5 also were used to calculate creek discharge for the fall survey series. Also the channel cross-section at this location was adjusted for the lake elevation for each survey. Velocity data were averaged at station 5 for surveys 7-12, and the resulting discharges obtained are shown in Plate 15. Discharges ranged from 110 to 170 cfs.

Selection of Test Conditions

Still-water level

24. Water levels on the Great Lakes fluctuate from year to year and from month to month. Also, at any given location, the water level can vary from day to day and from hour to hour. Continuous records of the levels of the Great Lakes, tabulated since 1860, indicate that the usual pattern of seasonal variations of water levels consists of highs in the summer and lows in the late winter. For Lake Ontario, the higher levels usually occur in June and the lower levels in January. For this study, lake els for the spring (April-June) and fall (August-October) seasons were obtained from the Great Lakes Acquisition Unit of the National Ocean Service. These data are shown in Plates 16-18 for spring conditions and Plates 19-21 for fall conditions. Points on the plots represent a 12-hr average of the lake level for each month. An average of these points for the spring season indicated a lake

level of +2.7 ft, and for the fall season, a lake level of +2.3 ft. Therefore, lake levels used for the temperatures and/or current effects tests were +2.7 and +2.3 ft for the spring and fall seasons, respectively.

Wave conditions

25. The prototype survey data obtained by the Fish and Wildlife Service included estimated wave heights in the lake for each survey. The data indicated waves with average heights of 2 ft for spring conditions and 7 ft for fall conditions. Based on wave characteristics and directions used in the previously reported investigation (Bottin and Acuff 1990) the following test waves were used for spring and fall conditions:

Season	Directions deg	Period sec	Height ft
Spring	42	4	2
Spring	343	4	2
Spring	313	4	2
Fall	42	6.4	7
Fall	343	6.4	7
Fall	313	6.4	7

Unidirectional wave spectra were used to represent these wave conditions.

Temperature variations

26. To determine test conditions for the model temperature effects tests, the difference in depth-averaged lake temperature (station 1) and the mean of the depth-averaged temperatures in the creek (station 3-5) were calculated. These are shown in Tables 2 and 3 for spring and fall conditions along with the average temperature difference for each season. A temperature differential of 3.8 deg C occurred for spring conditions and 0.6 deg C for the fall survey. For the model tests, the density differences resulting from the mean temperature differentials were reproduced, since the temperature of the water in the model basin and the Lake Ontario water were different.

Creek discharge

27. Discharge data obtained in Eighteenmile Creek during the spring and fall surveys were used to select representative flow rates. For the spring discharges, surveys 1,3,5, and 6 were considered. Discharge for Survey 2 was unusually large due to the snow melt and no data were available for survey 4. A discharge of 210 cfs was selected for spring conditions. For the fall

discharge, surveys 7-12 were considered and a flow rate of 145 cfs was selected for model testing.

Analysis of Model Data

28. During the temperature effects tests, the temperature of water in the lake was measured and warmer water was introduced into the creek with the correct density difference. The temperature of creek water and lake water was monitored until equilibrium was established, and then the water temperature was measured at selected locations and the corresponding densities calculated. The warmer creek water was dyed to determine its movement after it entered the lake. Data were analyzed to determine if trends in the model existed which were similar to those in the prototype. The performance of the model for various wave directions both with and without the improvement plan then was compared.

PART IV: TESTS AND RESULTS

The Tests

29. Current and temperature effects tests were conducted with existing conditions in the model and for the second basic improvement plan (Plan 19) tested previously (Bottin and Acuff 1990). The selected discharges and water temperature density differences were reproduced for three wave directions for both the spring and fall survey conditions. Even though another basic harbor configuration was developed previously (Plan 16), due to time and funding constraints, only Plan 19 was tested for current and temperature effects. Plan 19 enclosed the existing entrance with breakwaters more than Plan 16 and should be the worst case. Temperatures were recorded at various locations in the model (Plates 22 and 23) and wave pattern photographs as well as videotape footage were obtained for existing conditions and the improvement plan.

Test Results

Spring conditions

30. The temperature of the water in the lake and that introduced into the creek for spring conditions are shown in Table 4 prior to the conduct of tests for existing conditions and Plan 19. Note the density difference of the water ranged from 0.00134 to 0.00138 slugs/ft^3. Density differences in the prototype between the lake water and creek water were 0.00136 slugs/ft^3. Temperature data obtained for existing conditions and Plan 19 are shown in Table 5 for waves from the three directions. These data were recorded after equilibrium was established. Current patterns and the movement of the plume as the creek water entered the lake are shown in Photos 3-8 for the three wave directions.

31. Initially, comparison of existing condition model data for test waves from 42 deg with prototype data for the spring period indicated that similar trends were established. The temperature at gage 2 begins to decrease due to the influence of the cooler lake water. Further analysis also indicated cooler temperatures at the bottom depth with slightly warmer temperatures at the surface for both the model and prototype. The plume also moved in a westerly direction for both conditions. Since comparisons for existing

conditions and the prototype were similar, relative comparisons between existing conditions and the improvement plan should be valid.

32. Comparisons of temperature data for existing conditions and Plan 19 reveal similar trends in the entrance and the lake. Gage 2 began feeling the influence of the cooler lake water for existing conditions and the improvement plan (i.e. its temperature was between that of the lake water and the creek water). Also the path of the creek plume moved in the same directions along the shoreline depending on the incident direction of wave approach for both the improvement plan and existing conditions. The path of the plume in the immediate area between the existing creek mouth and the new breakwater entrance varied slightly, however, on a more regional basis creek movement into the lake and along the shorelines was similar.

Fall conditions

33. The temperature of water in the lake and that introduced into the creek during tests for fall conditions are shown in Table 6 for existing conditions and Plan 19. The density difference of the water ranged from 0.00020 to 0.00024 slugs/ft^3. Density difference in the prototype between the lake water and creek water was 0.00020 slugs/ft^3. Due to the very slight temperature variation and corresponding density difference between the lake and creek water, measurement of temperature in the model were not obtained for fall conditions. Such a slight change in temperature in the model would be extremely difficult to accurately measure due to slight fluctuations, and spring conditions (with a greater temperature variation) had already established trends. The creek water was heated as shown in Table 6, however, for the current and creek plume movement tests.

34. Current patterns and the movement of the plume as the creek water entered the lake are shown in Photos 9-14 for test waves from the three directions for fall conditions with existing conditions and Plan 19 installed. A comparison of these data indicates that the path of the creek plume moved in the same directions along the shoreline after they entered the lake, depending on the direction of wave approach. Again, as for spring conditions, the movement of the creek water in the immediate area between the existing jetties and the new breakwater entrance varied slightly in this localized area, but on a regional basis, creek current movement into the lake and along the shoreline was similar.

PART V: CONCLUSIONS

35. Based on the results of the hydraulic model investigation reported herein, it is concluded that:

a. Existing conditions in the model accurately reproduced trends established in the prototype with regard to temperature variations between the creek and the lake water and the movement of the creek plume as it entered Lake Ontario.

b. Comparisons of existing conditions and the new breakwater Plans (Plan 19) revealed similar trends in the entrance and lake with regard to temperature variations.

c. Comparisons of existing conditions and Plan 19 indicated that the movement of the creek plume into the lake and along the shorelines was similar on a regional basis and varied only slightly in a localized area at the entrance.

d. The installation of the proposed improvements at the mouth of Eighteenmile Creek should have no adverse impact on temperature variations or the movement of creek water into the lake and along the shoreline.

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Table 1

Dates for Spring and Fall Field Surveys Conducted by the Fish and Wildlife Service at Olcott, New York

Spring Survey	Date
1	25 April 1989
2	9 May 1989
3	23 May 1989
4	6 June 1989
5	20 June 1989
6	6 July 1989
Fall Survey	**Date**
7	23 August 1989
8	5 September 1989
9	18 September 1989
10	3 October 1989
11	18 October 1989
12	1 November 1989

Table 2

Depth-Averaged Temperature Difference Between Station 1 and the Mean of Stations 3-5, deg C, for Surveys 1-6

	Station				Average	
Survey	1	3	4	5	Stations 3-5	Difference
1	8.3	10.1	13.0	11.7	11.6	3.3
2*	8.5	7.1*	8.2*	7.2*	7.5*	-1.0*
3	13.1	18.1	15.4	17.2	16.9	3.8
4	15.5	19.0	19.8	19.5	19.4	3.9
5	15.4	18.3	19.5	18.3	18.7	3.3
6	18.6	23.4	24.2	22.8	23.5	4.9
					Average	3.8

* Survey results influenced by snow melt and not used in average of temperature difference.

Table 3

Depth-Averaged Temperature Difference Between Station 1 and the Mean of Stations 3-5, deg C, for Surveys 7-12

Survey	Station 1	Station 3	Station 4	Station 5	Average Stations 3-5	Difference
7	21.0	22.0	22.0	22.3	22.1	1.1
8	20.1	20.5	20.5	21.0	20.7	0.6
9	18.3	18.5	17.4	17.5	17.8	-0.5
10	13.5	14.6	14.6	14.5	14.6	1.1
11	--	--	--	--	--	--
12	--	13.0	12.4	11.7	12.4	--
					Average	0.6

-- Indicates temperature gage inoperative during survey

Table 4

Temperature of Water in Lake and Water Introduced into Creek for Various Tests for Spring Conditions

Wave Direction deg	Temperature of Water in Lake Prior to Tests, deg C	Temperature of Water Introduced into Creek, deg C	Density Difference, $slugs/ft^3$
	Existing Conditions		
42	19.1	22.9	0.00134
343	19.8	23.7	0.00138
313	21.7	25.4	0.00136
	Plan 19		
42	21.4	25.2	0.00138
343	19.3	23.2	0.00138
313	19.7	23.5	0.00138

Table 5

Temperature Data Obtained in the Model for Existing Conditions and Plan 19 for Spring Conditions

Wave Direction deg	Sta 1	Sta 2	Sta 3	Sta 4	Sta 5	Sta 6	Sta 7	Sta 8	Sta 9
				Existing Conditions					
42	22.9	21.4	20.3	20.4	20.1	19.9	20.1	19.6	21.1
343	23.2	22.4	20.3	19.8	20.7	20.6	20.3	19.9	20.5
313	25.1	24.8	21.8	21.7	22.0	21.8	21.7	21.6	21.8
				Plan 19					
42	25.2	23.5	22.1	22.3	22.1	22.1	21.8	21.5	22.9
343	23.1	23.2	20.0	19.5	19.5	19.6	19.5	19.6	19.5
313	23.5	23.3	20.7	20.6	20.6	20.7	20.1	20.2	21.0

Table 6

Temperature of Water in Lake and Water Introduced into Creek for Various Tests for Fall Conditions

Wave Direction deg	Temperature of Water in Lake Prior to Tests, deg C	Temperature of Water Introduced into Creek, deg C	Density Difference, slugs/ft^3
	Existing Conditions		
42	17.4	18.1	0.00024
343	17.1	17.7	0.00020
313	17.4	18.1	0.00024
	Plan 19		
42	13.1	13.7	0.00022
343	11.9	12.5	0.00020
313	12.5	13.2	0.00024

Photo 1. View of the first basis harbor configuration (with the proposed mooring area east of the existing entrance, Plan 16) developed in the previous investigation

Photo 2. View of the second basic harbor configuration (with proposed mooring areas east and west of the existing entrance, Plan 19) developed in the previous investigation

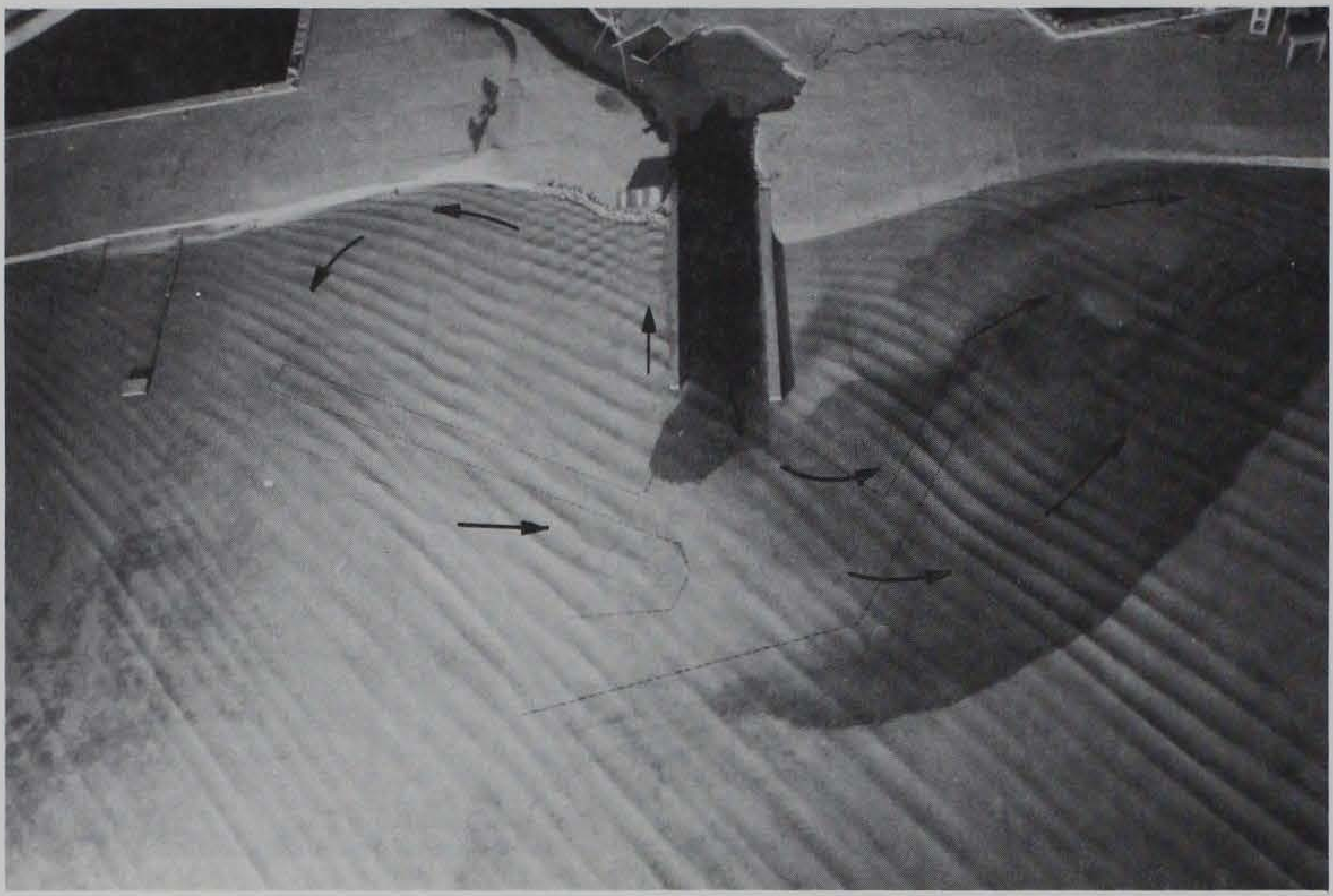


Photo 3. Current patterns and movement of creek plume for existing conditions for test waves from 42 deg during spring conditions

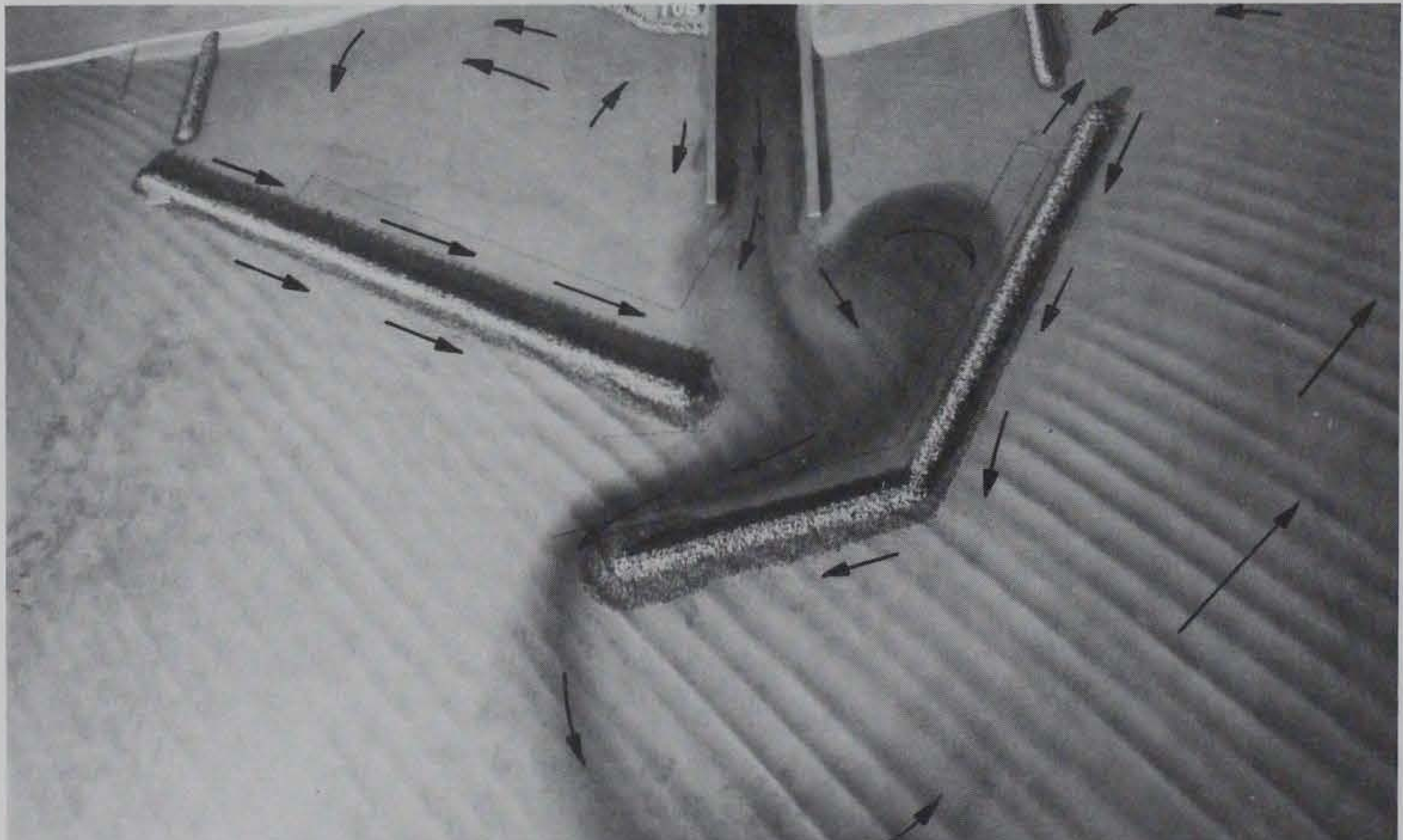


Photo 4. Current patterns and movement of creek plume for Plan 19 for test waves from 42 deg during spring conditions

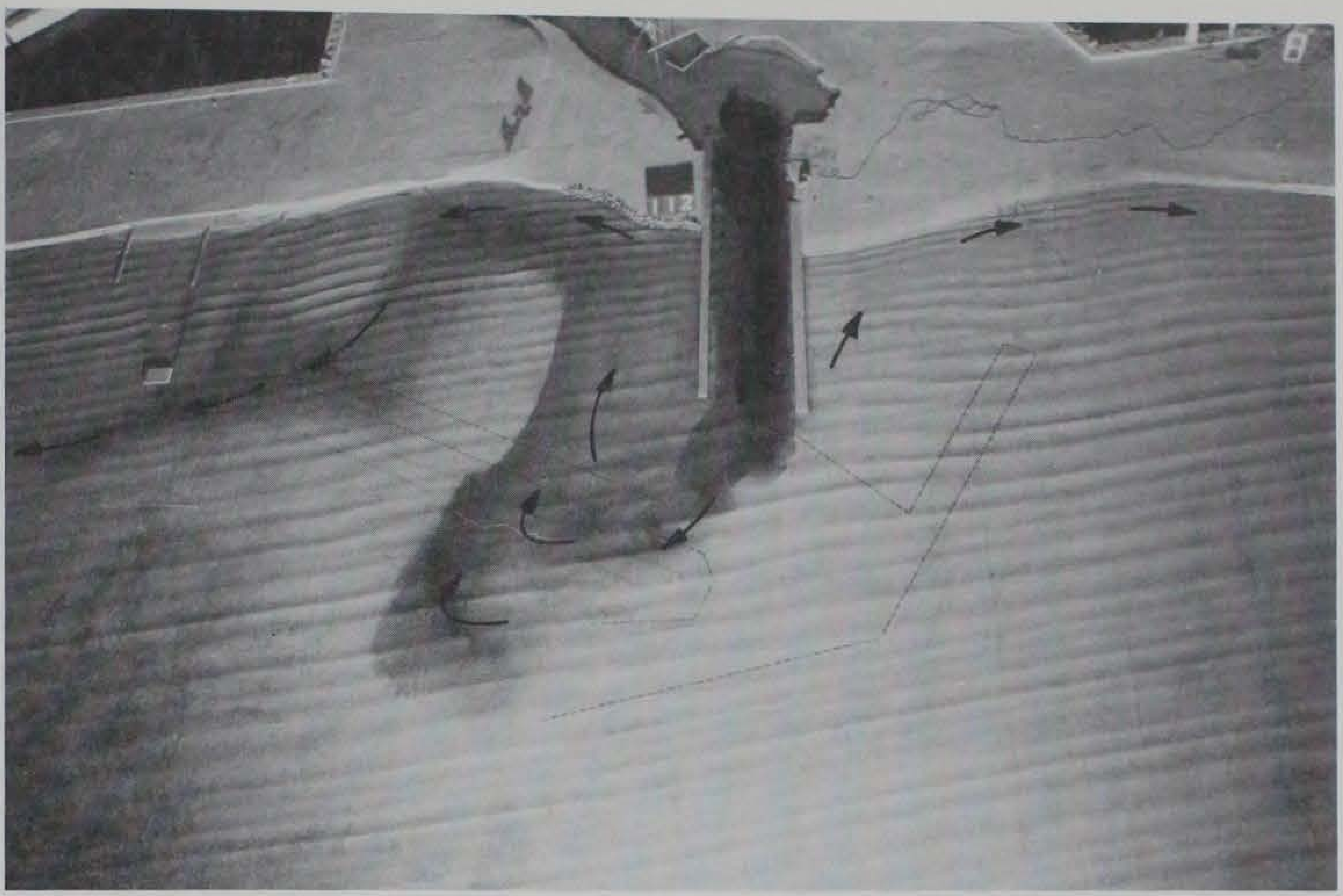


Photo 5. Current patterns and movement of creek plume for existing conditions for test waves from 343 deg during spring conditions

Photo 6. Current patterns and movement of creek plume for Plan 19 for test waves from 343 deg during spring conditions

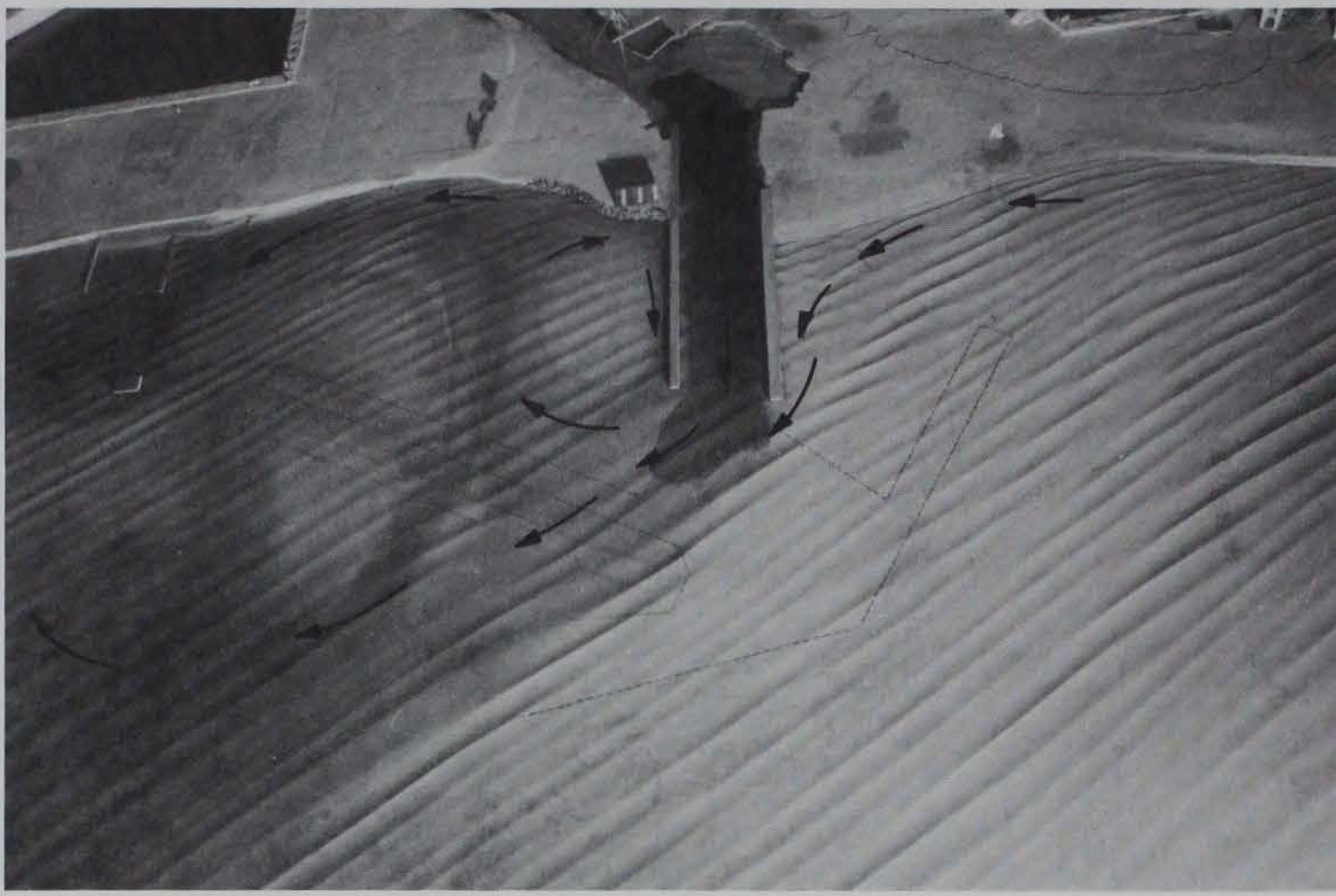


Photo 7. Current patterns and movement of creek plume for existing conditions for test waves from 313 deg during spring conditions

Photo 8. Current patterns and movement of creek plume for Plan 19 for test waves from 313 deg during spring conditions

Photo 9. Current patterns and movement of creek plume for existing conditions for test waves from 42 deg during fall conditions

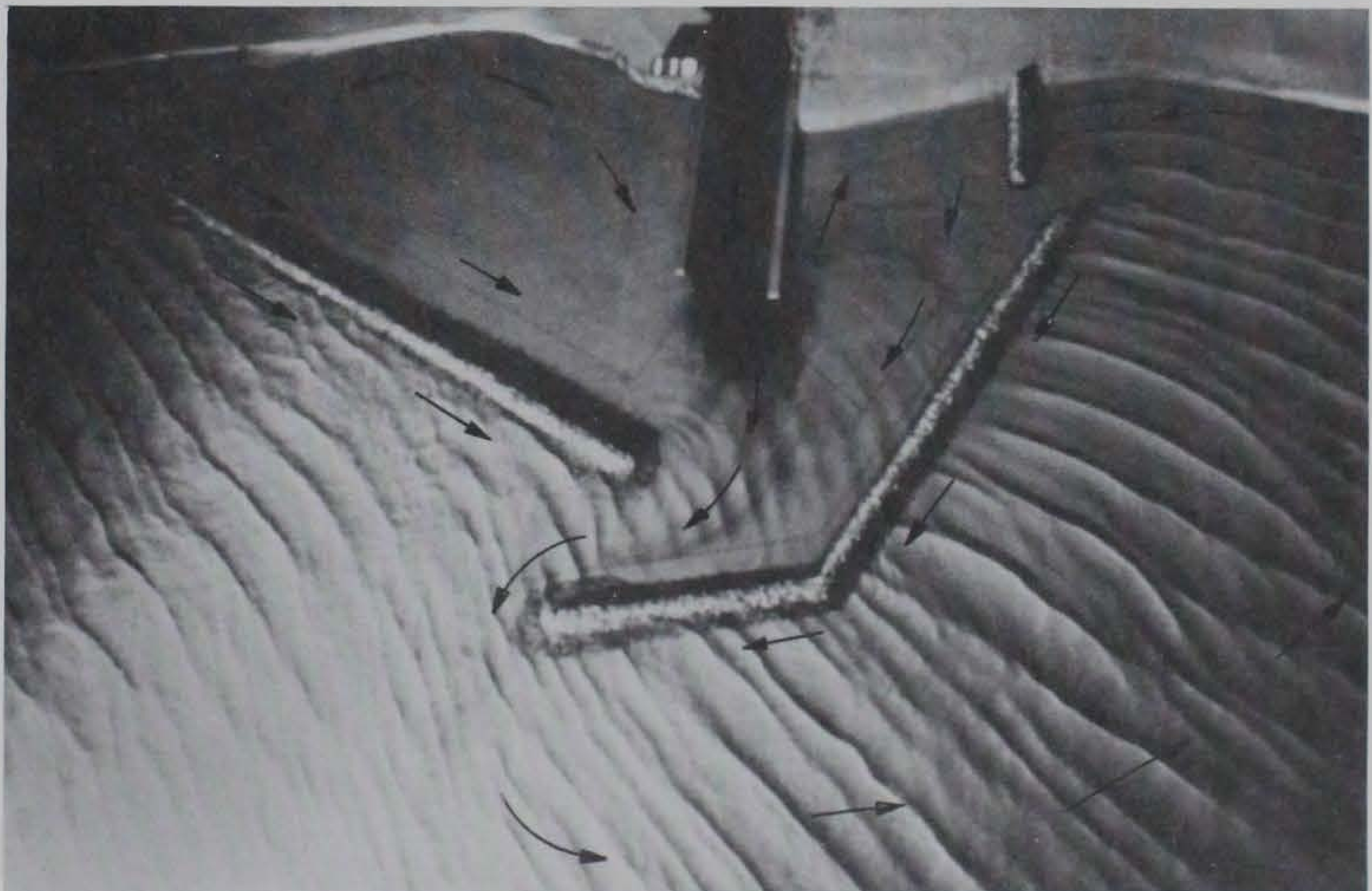


Photo 10. Current patterns and movement of creek plume for Plan 19 for test waves from 42 deg during fall conditions

Photo 11. Current patterns and movement of creek plume for existing conditions for test waves from 343 deg during fall conditions

Photo 12. Current patterns and movement of creek plume for Plan 19 for test waves from 343 deg during fall conditions

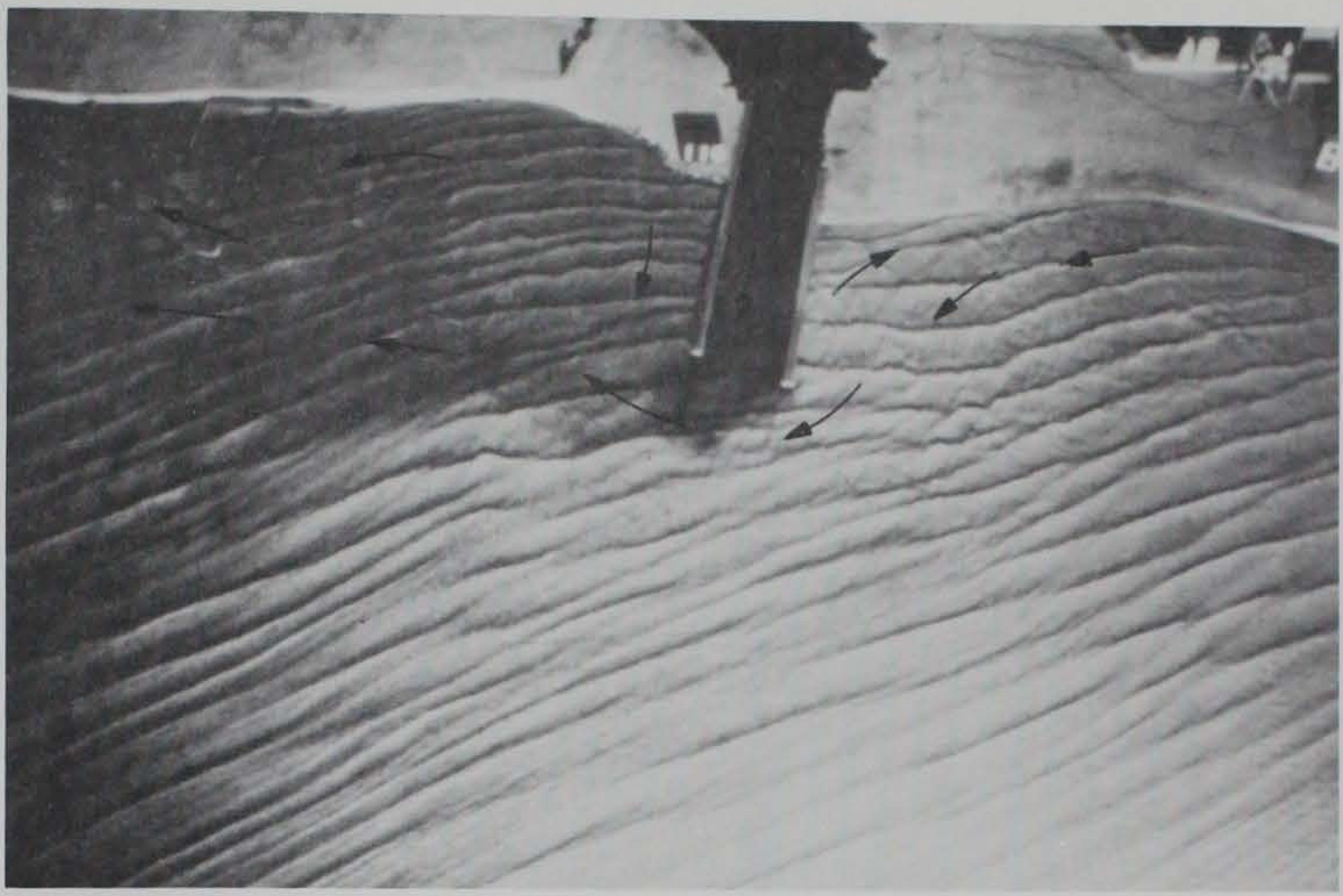
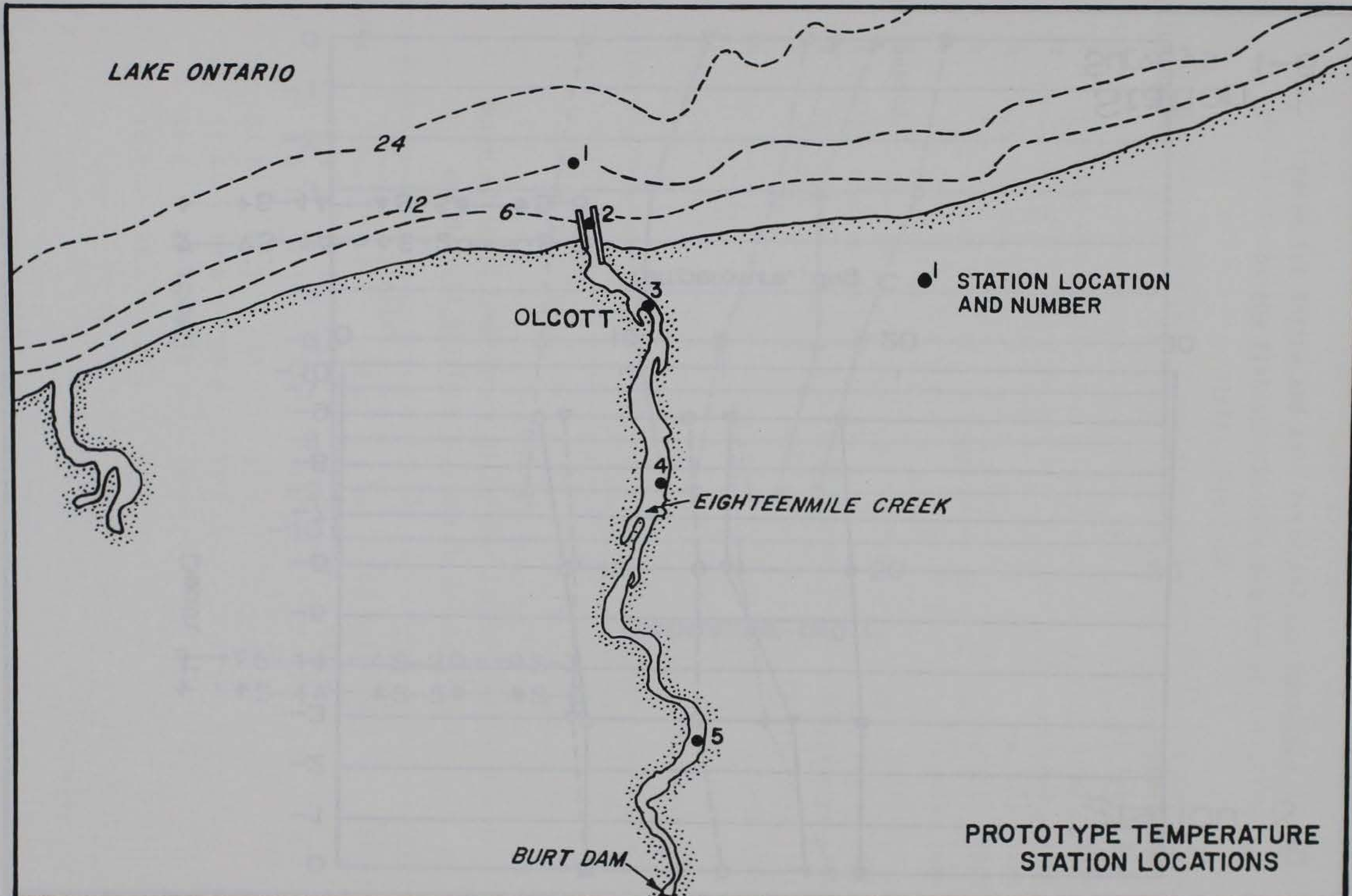


Photo 13. Current patterns and movement of creek plume for existing conditions for test waves from 313 deg during fall conditions

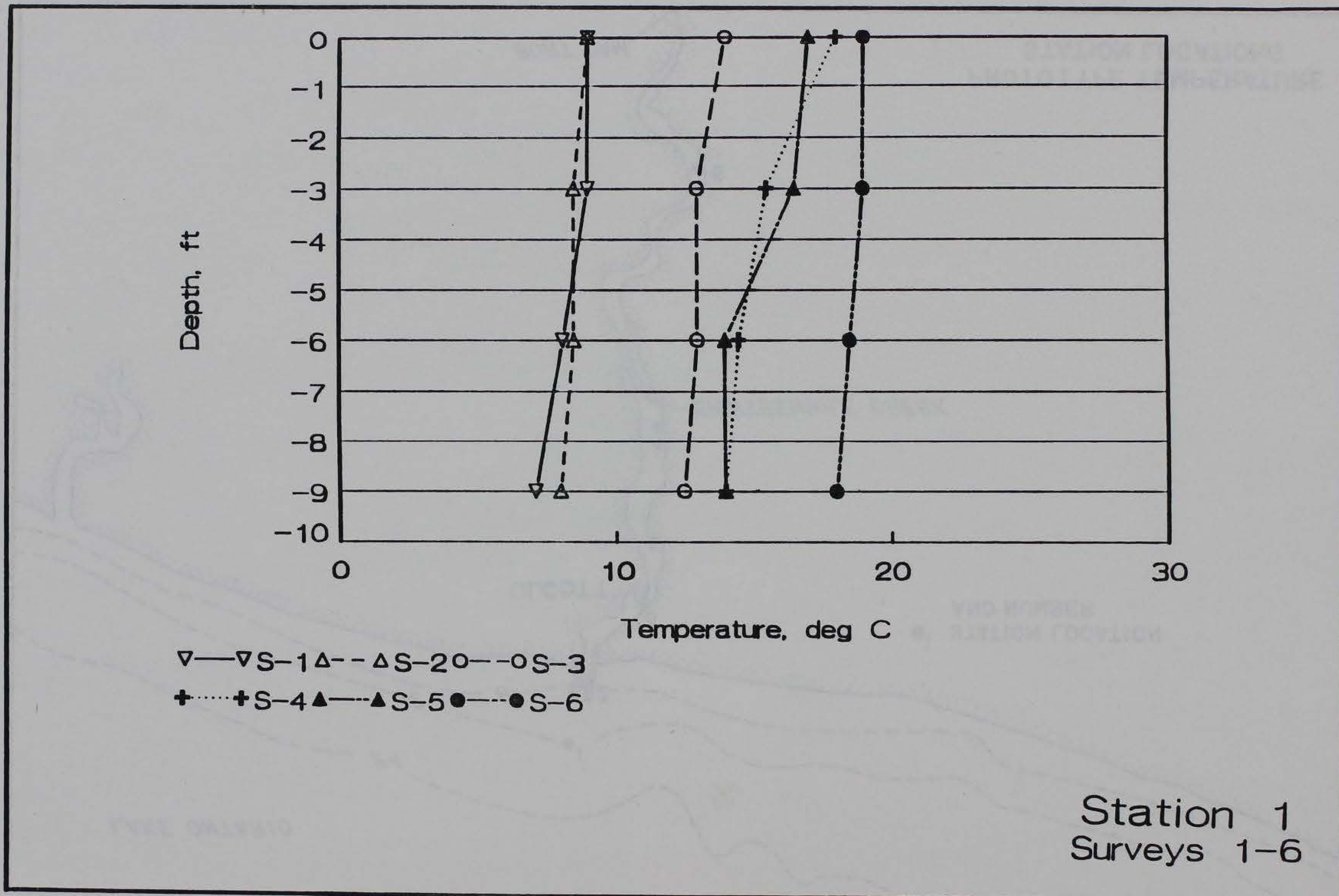
Photo 14. Current patterns and movement of creek plume for Plan 19 for test waves from 313 deg during fall conditions



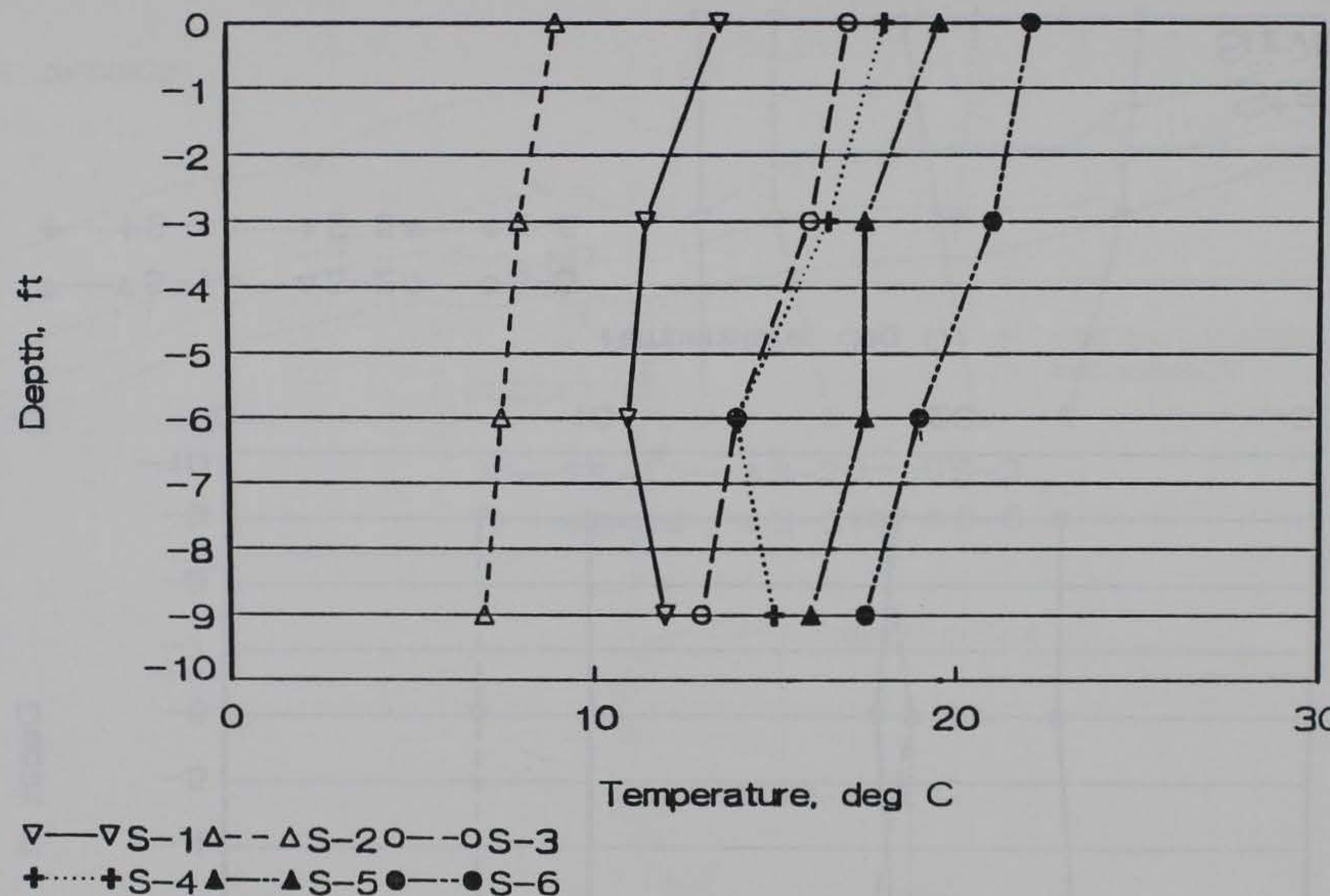
PROTOTYPE TEMPERATURE STATION LOCATIONS

PLATE 1

PLATE 2

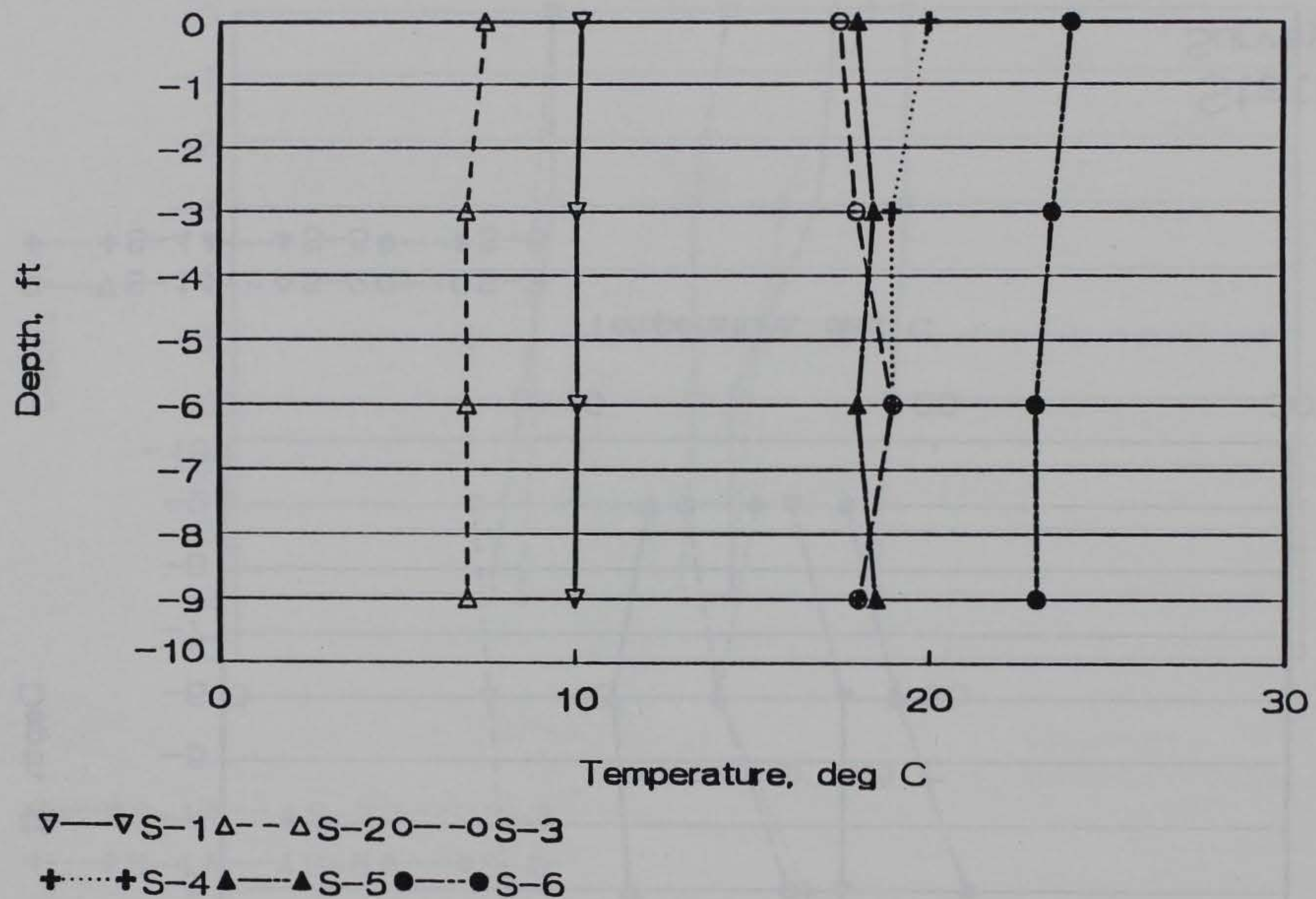


0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
Depth, ft
0
10
20
30
Temperature, deg C
S−1
S−2
S−3
S−4
S−5
S−6
Station 1
Surveys 1−6

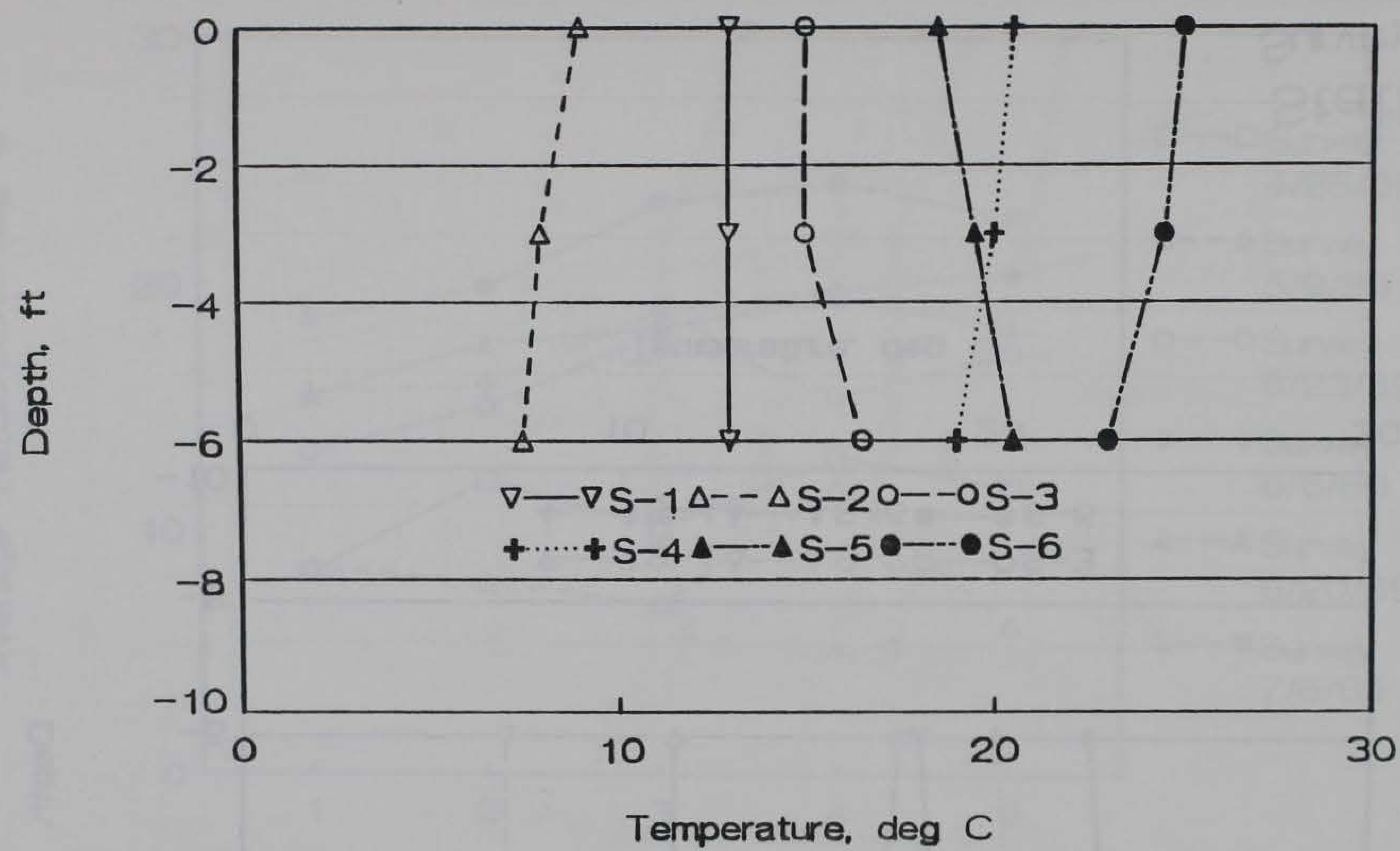


Station 2
Surveys 1-6

PLATE 4

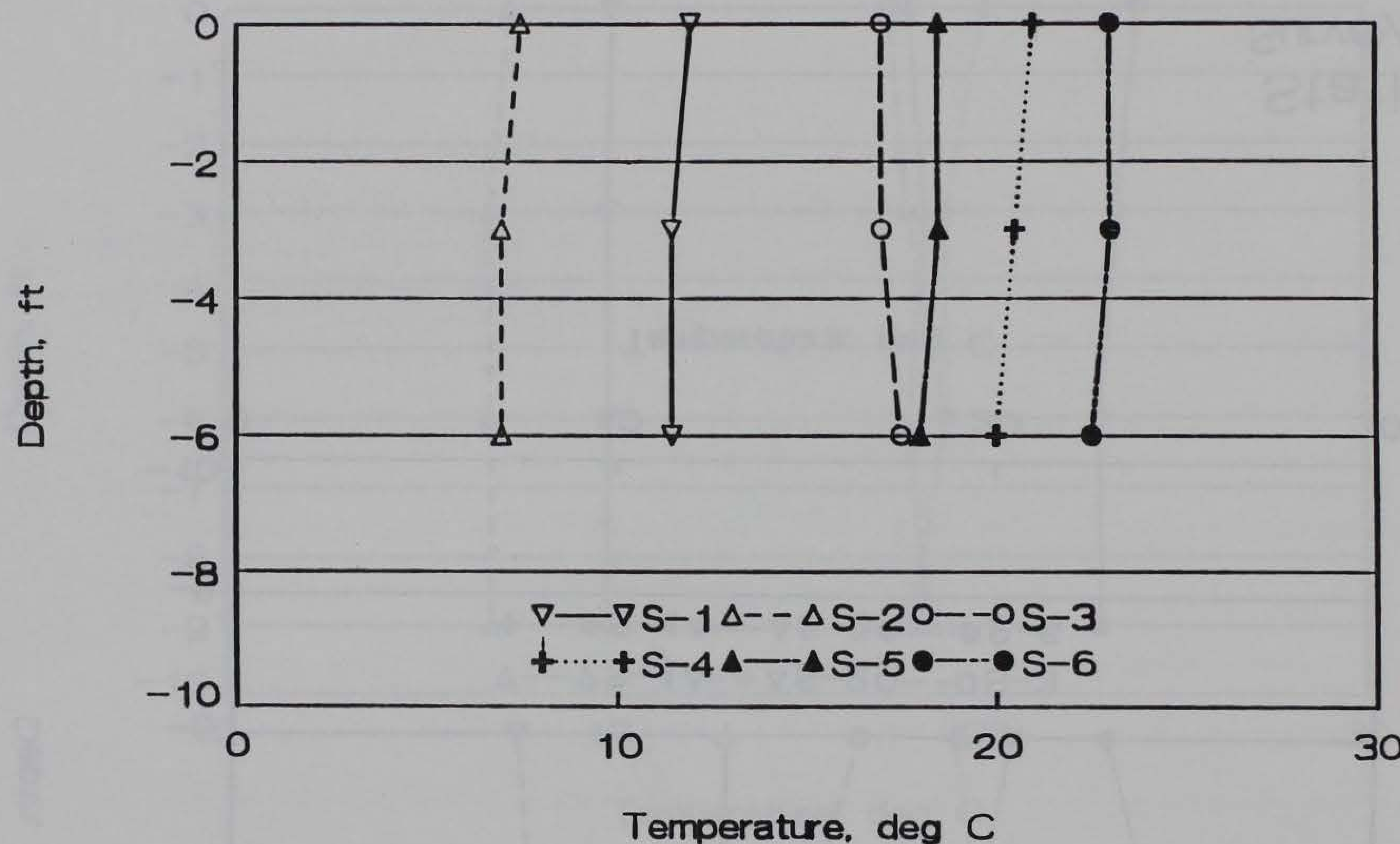


Station 3
Surveys 1-6

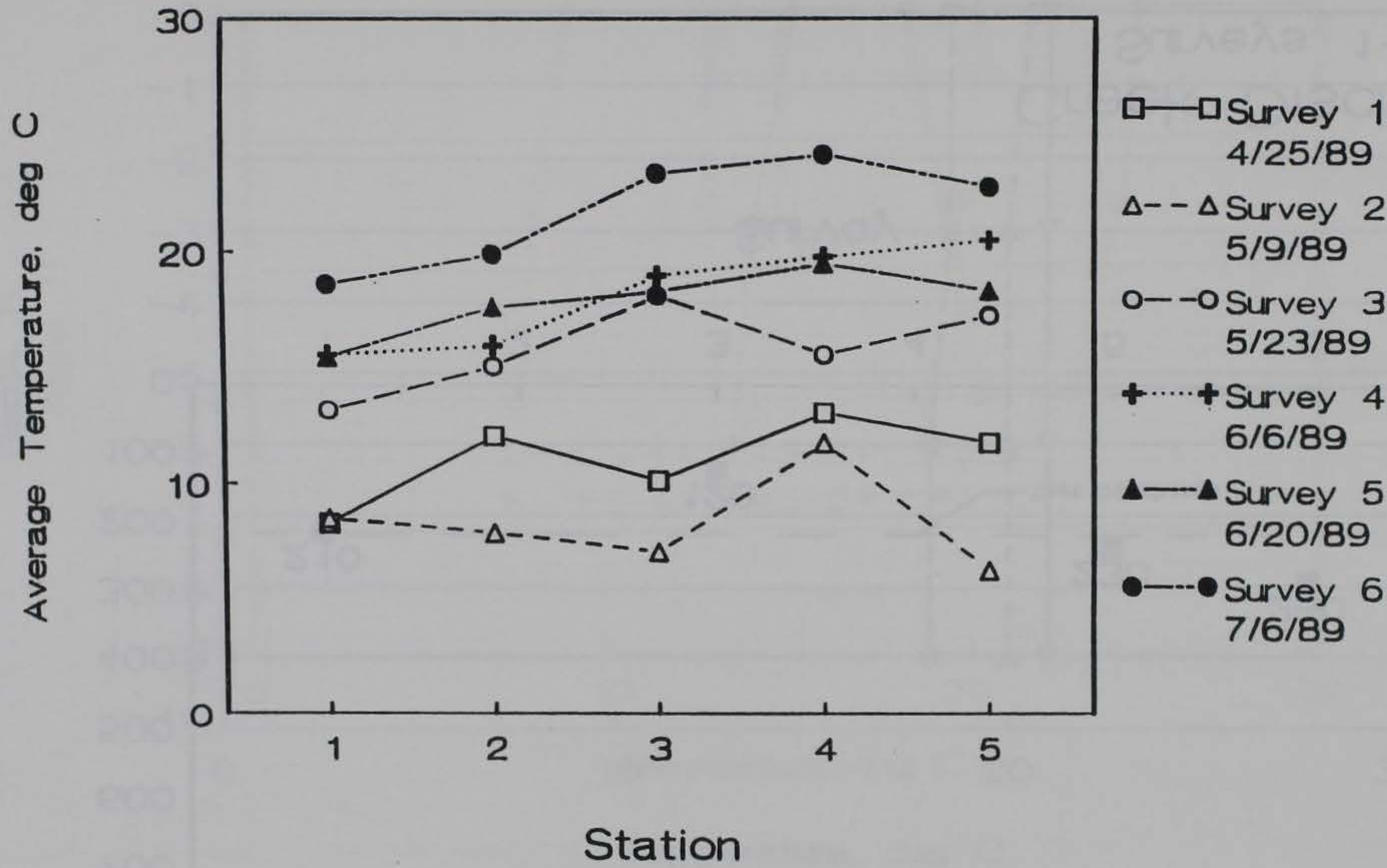


Station 4
Surveys 1-6

PLATE 6



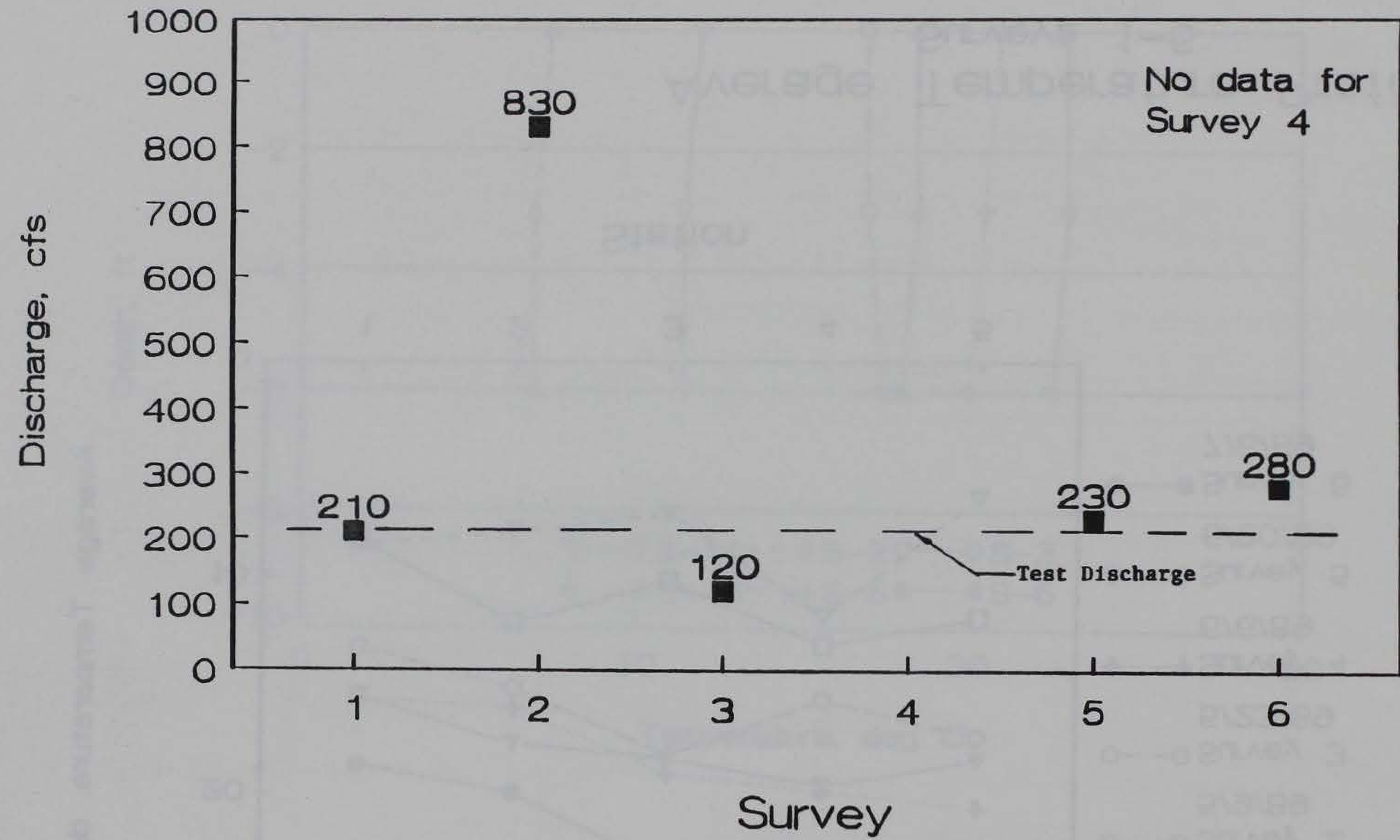
Station 5
Surveys 1–6



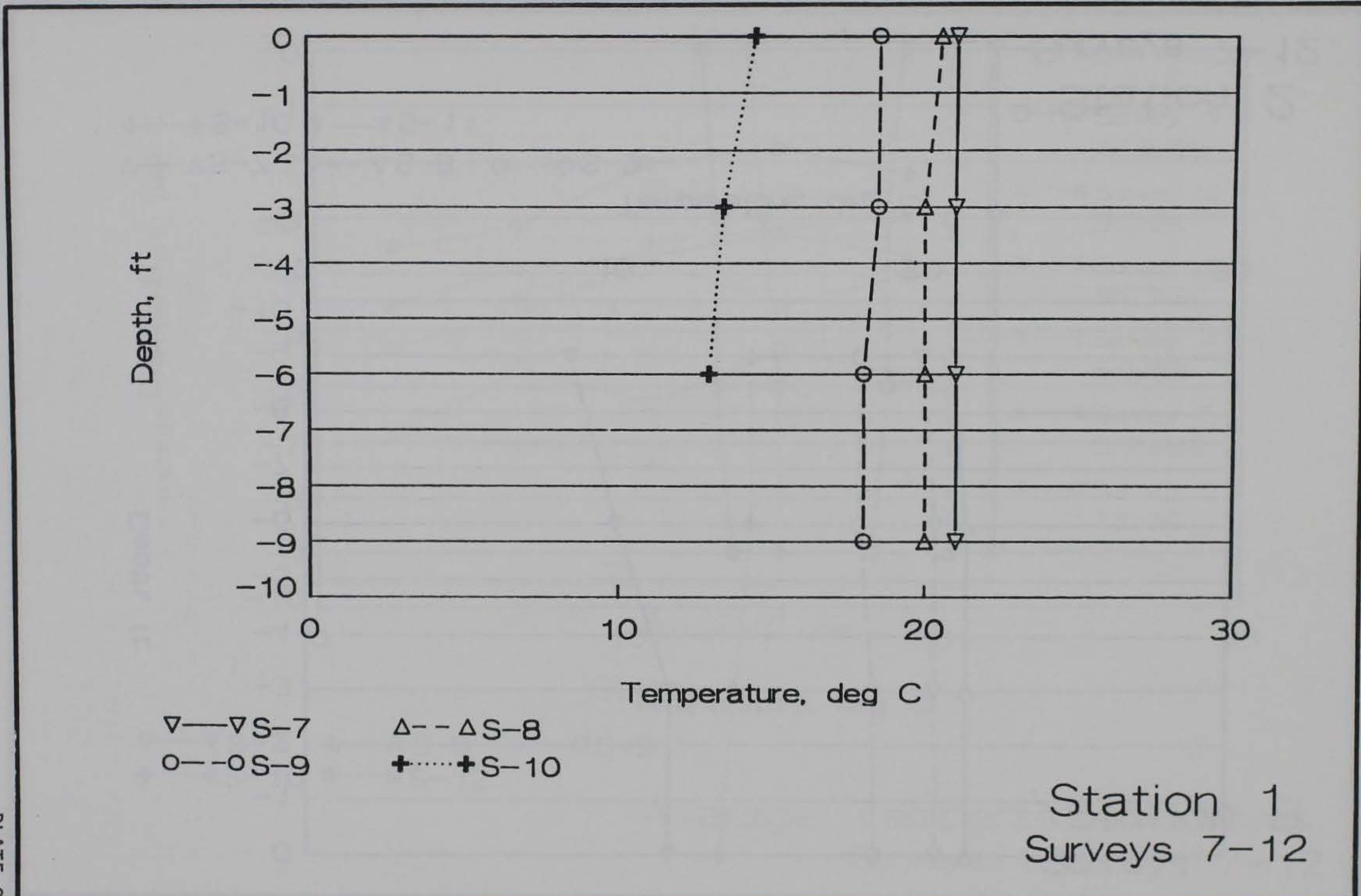
Average Temperature Profiles
Surveys 1–6

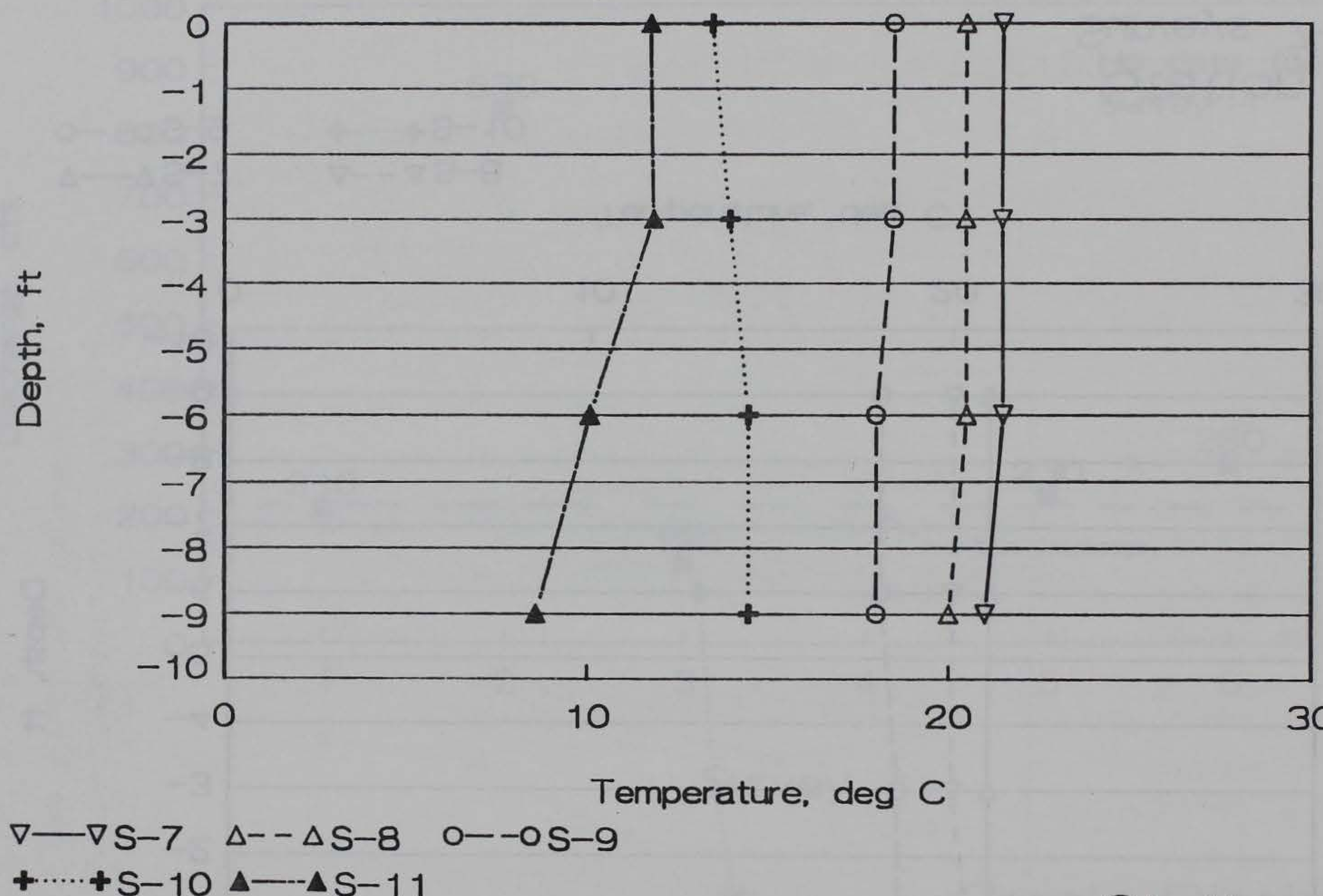
PLATE 7

PLATE 8



Creek Discharge
Surveys 1–6


0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
Depth, ft
0
10
20
30
Temperature, deg C
S−7
S−8
S−9
S−10
Station 1
Surveys 7−12



Station 2
Surveys 7-12

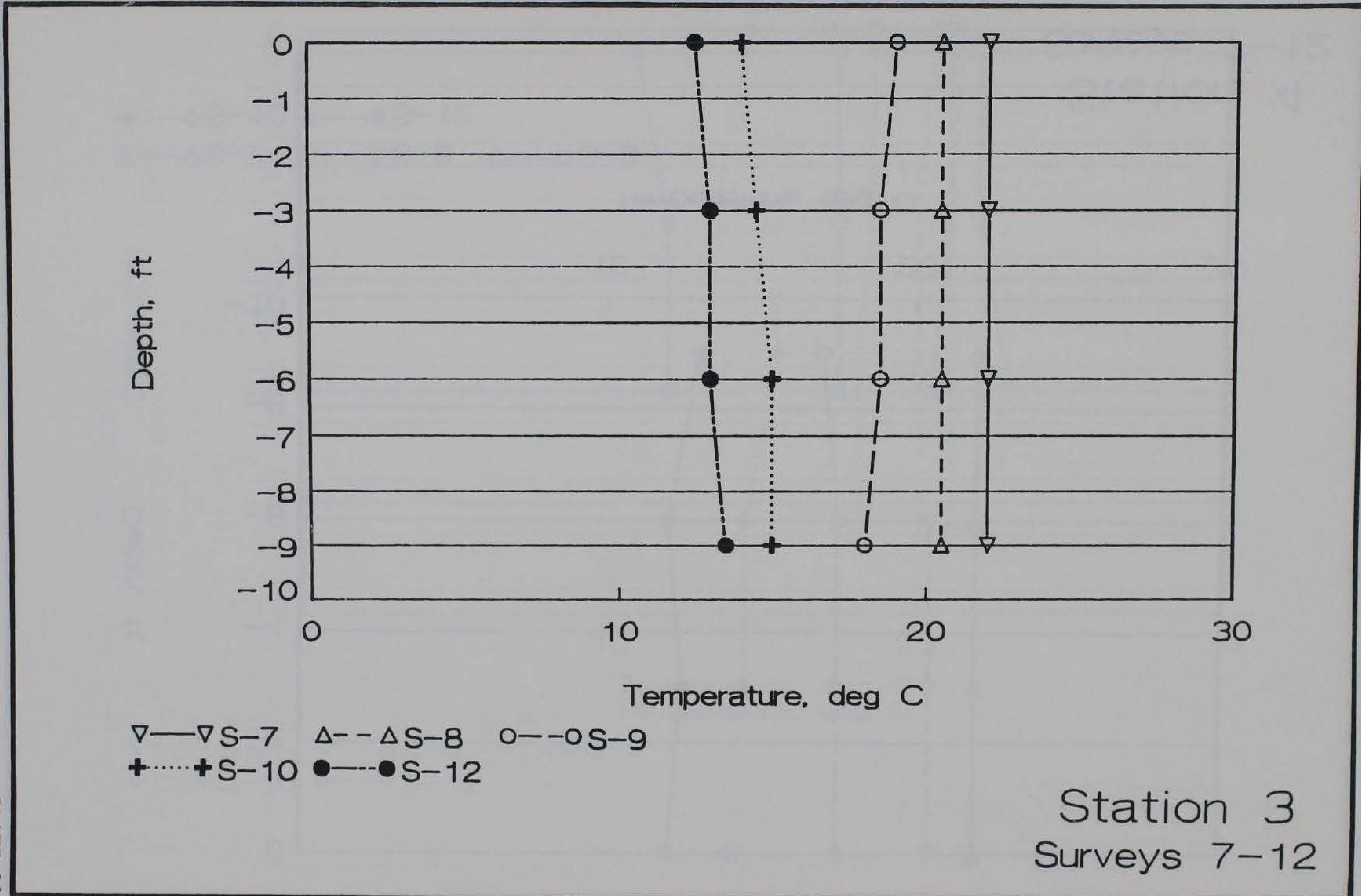
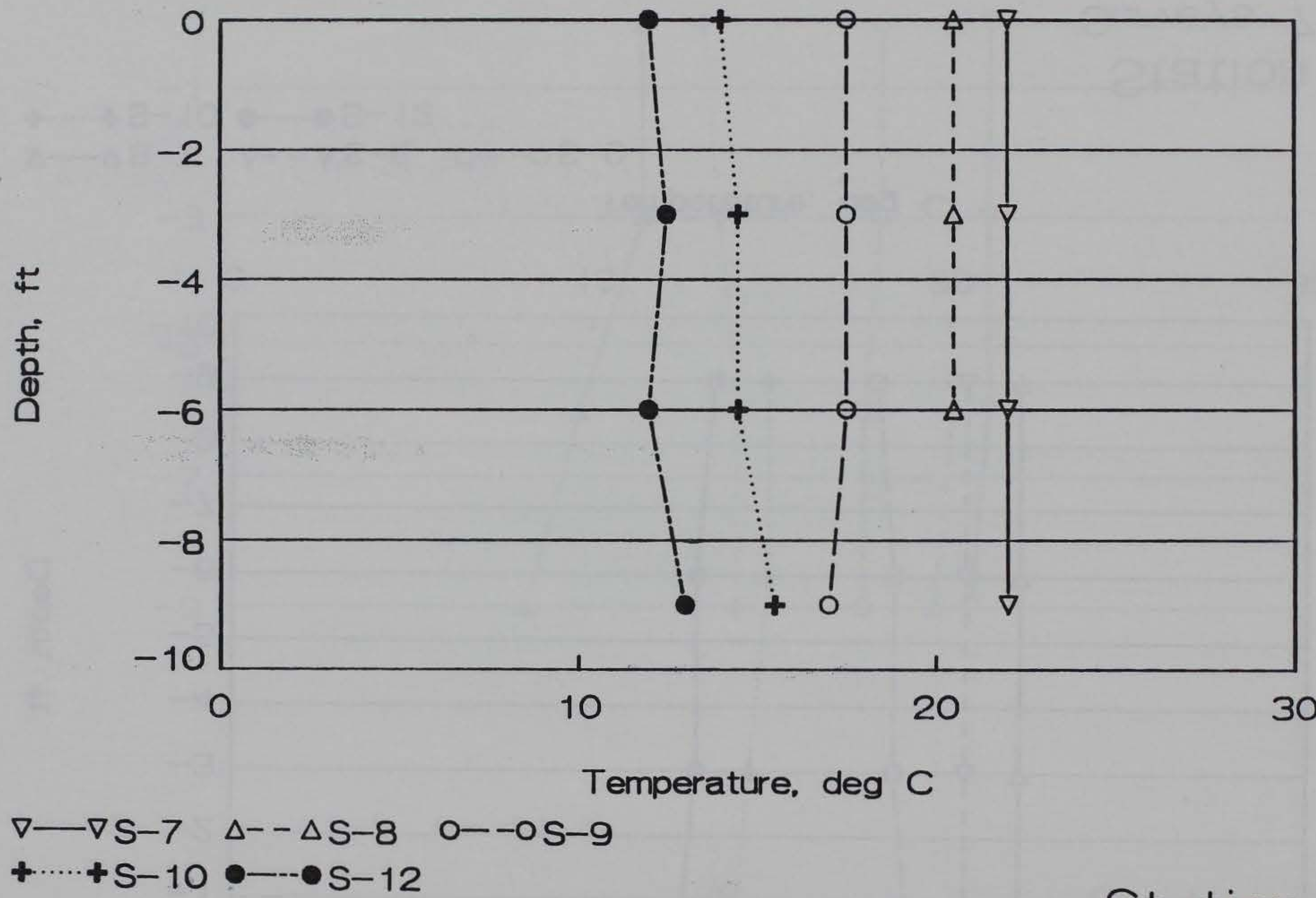
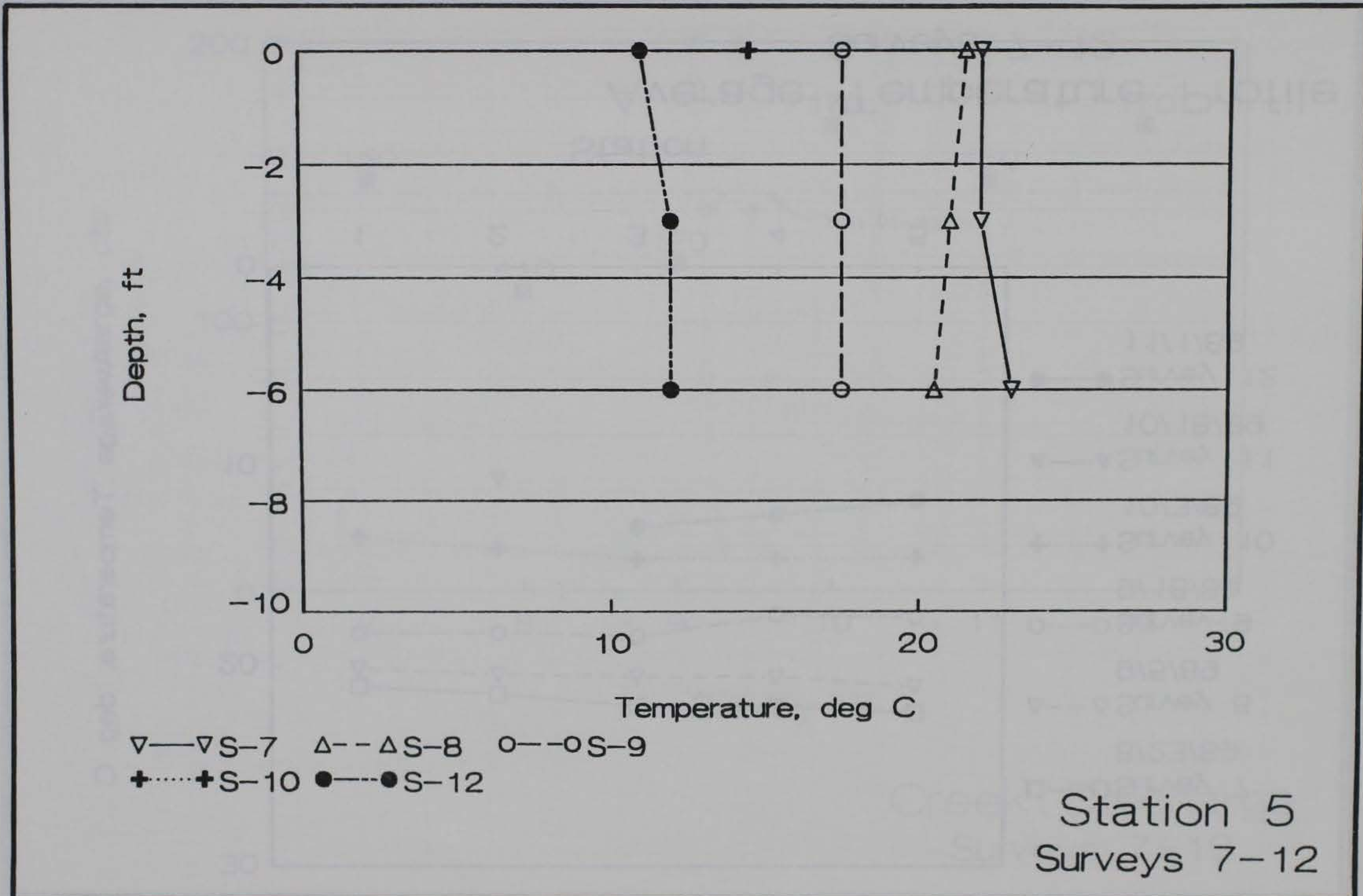

0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
Depth, ft
0
10
20
30
Temperature, deg C
S−7
S−8
S−9
S−10
S−12
Station 3
Surveys 7−12

PLATE 12

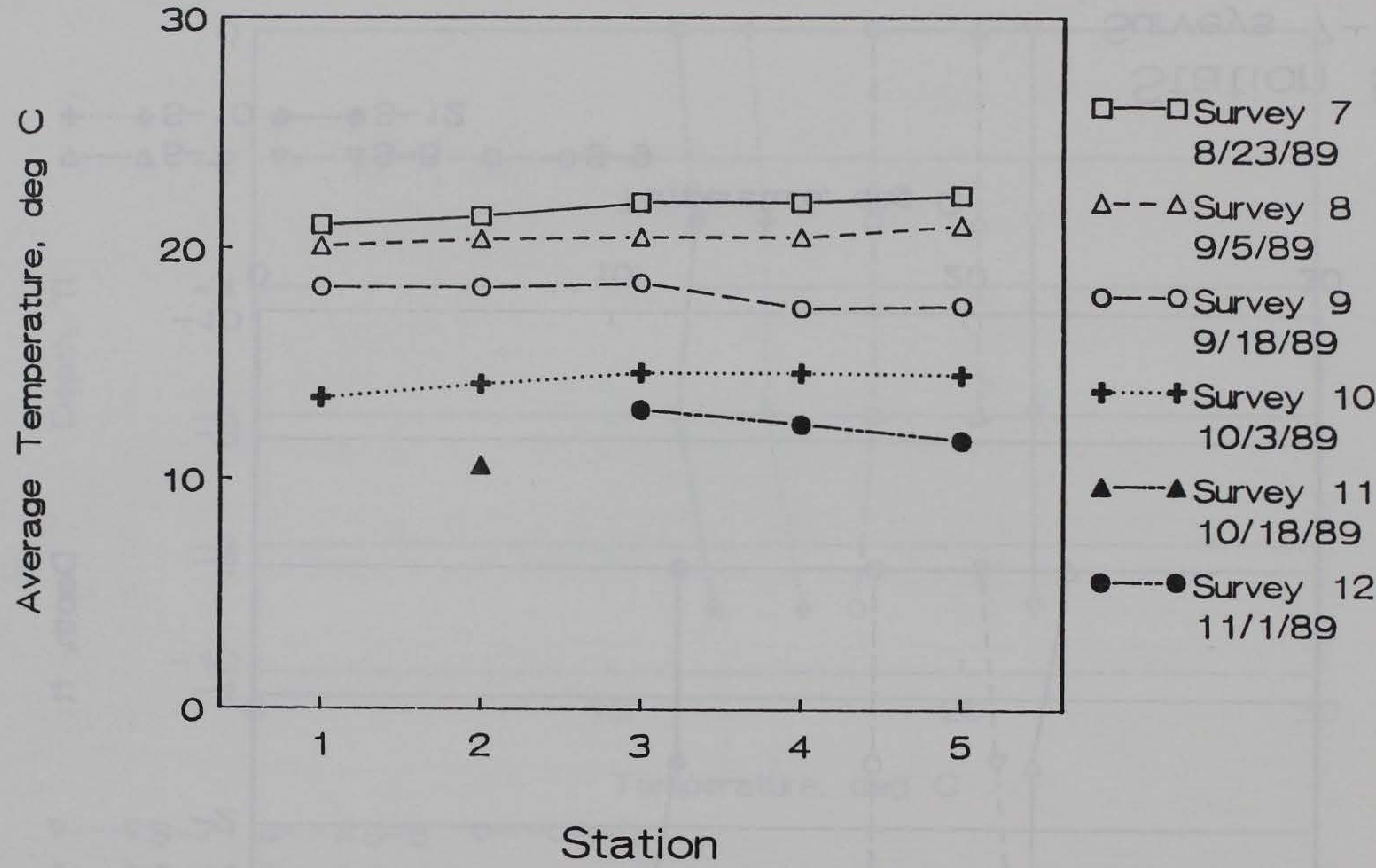


Station 4
Surveys 7--12

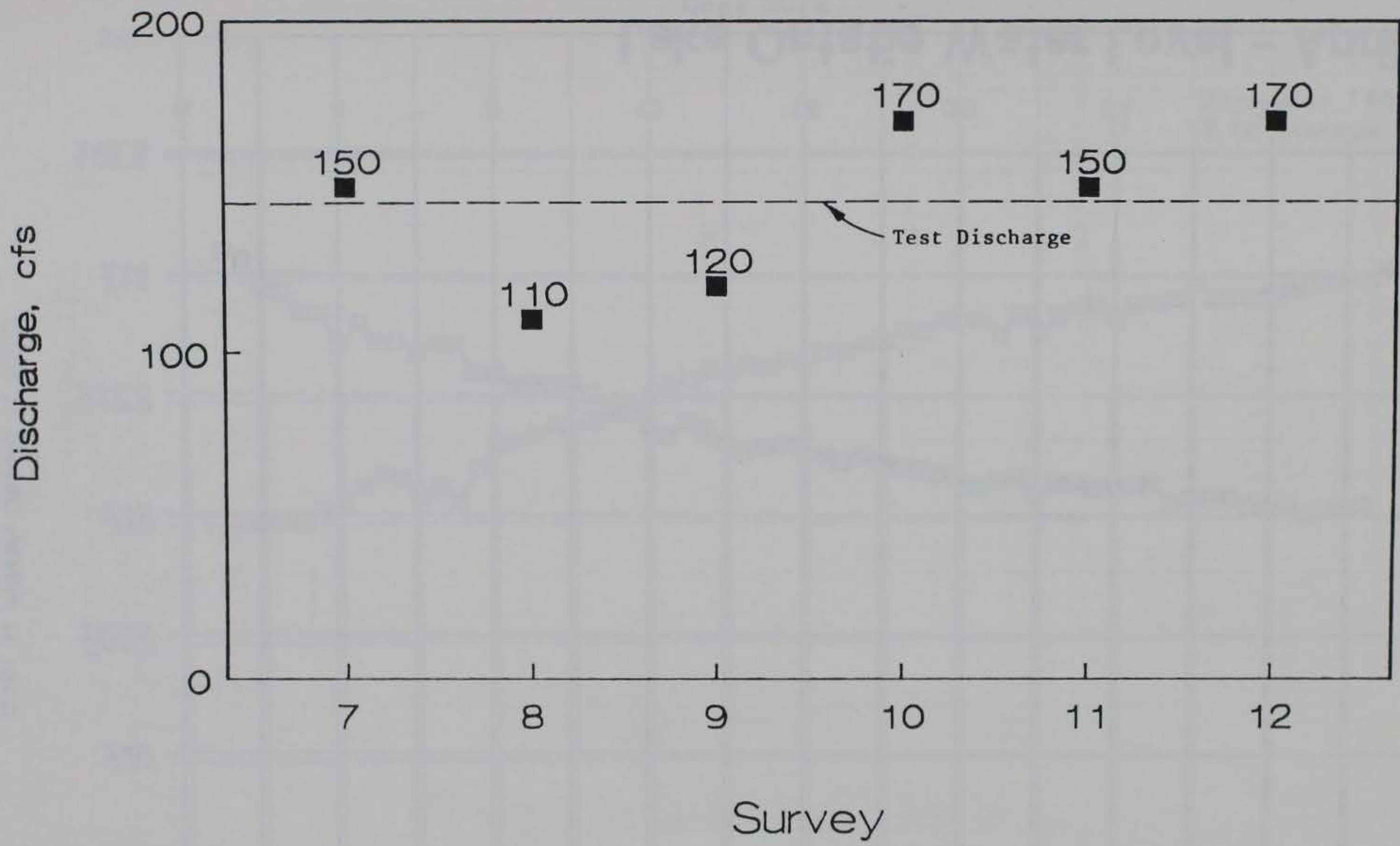


0
-2
-4
-6
-8
-10
Depth, ft
0
10
20
30
Temperature, deg C
S-7
S-8
S-9
S-10
S-12
Station 5
Surveys 7-12

PLATE 14

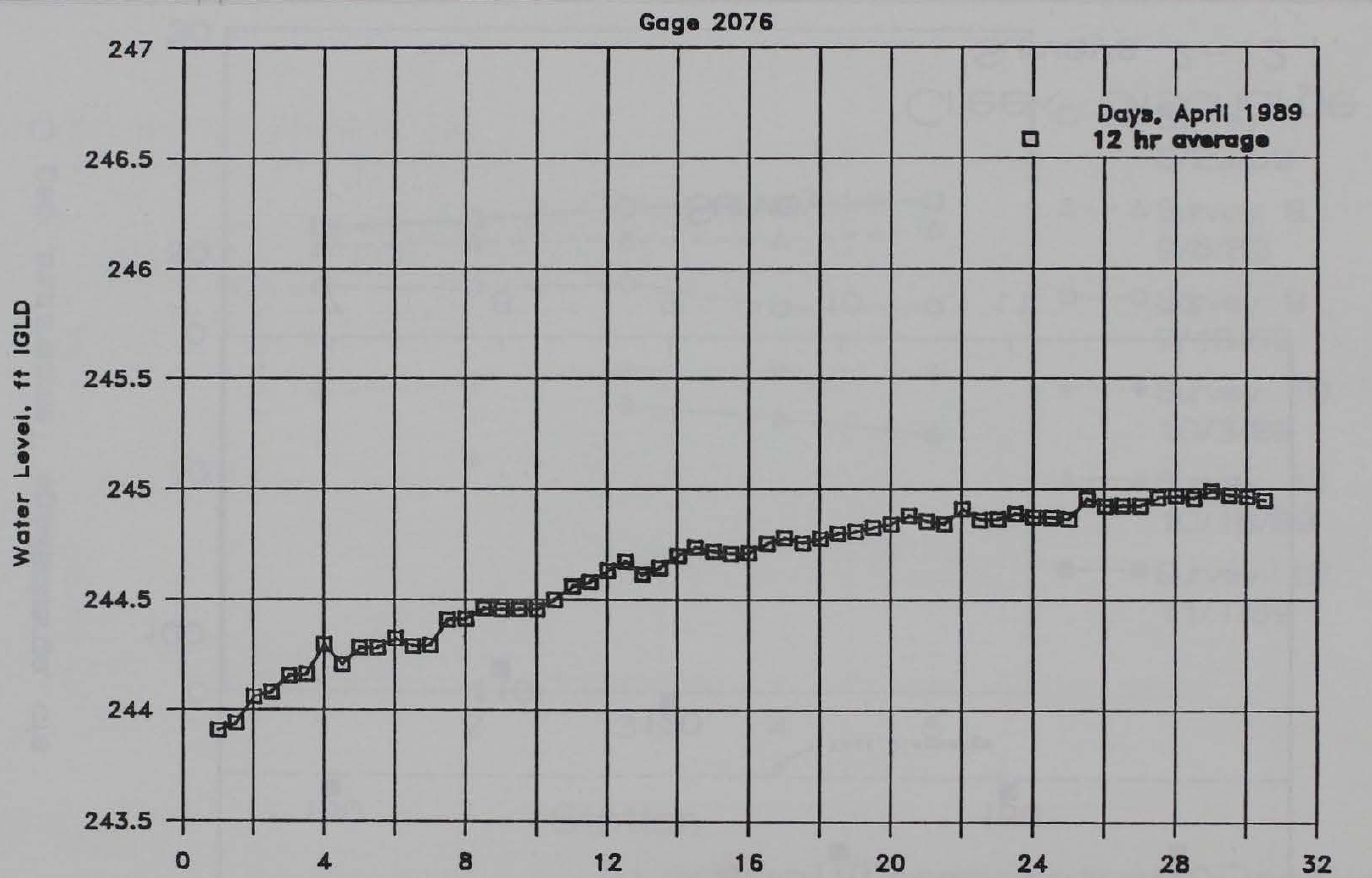


Average Temperature Profile
Surveys 7–12

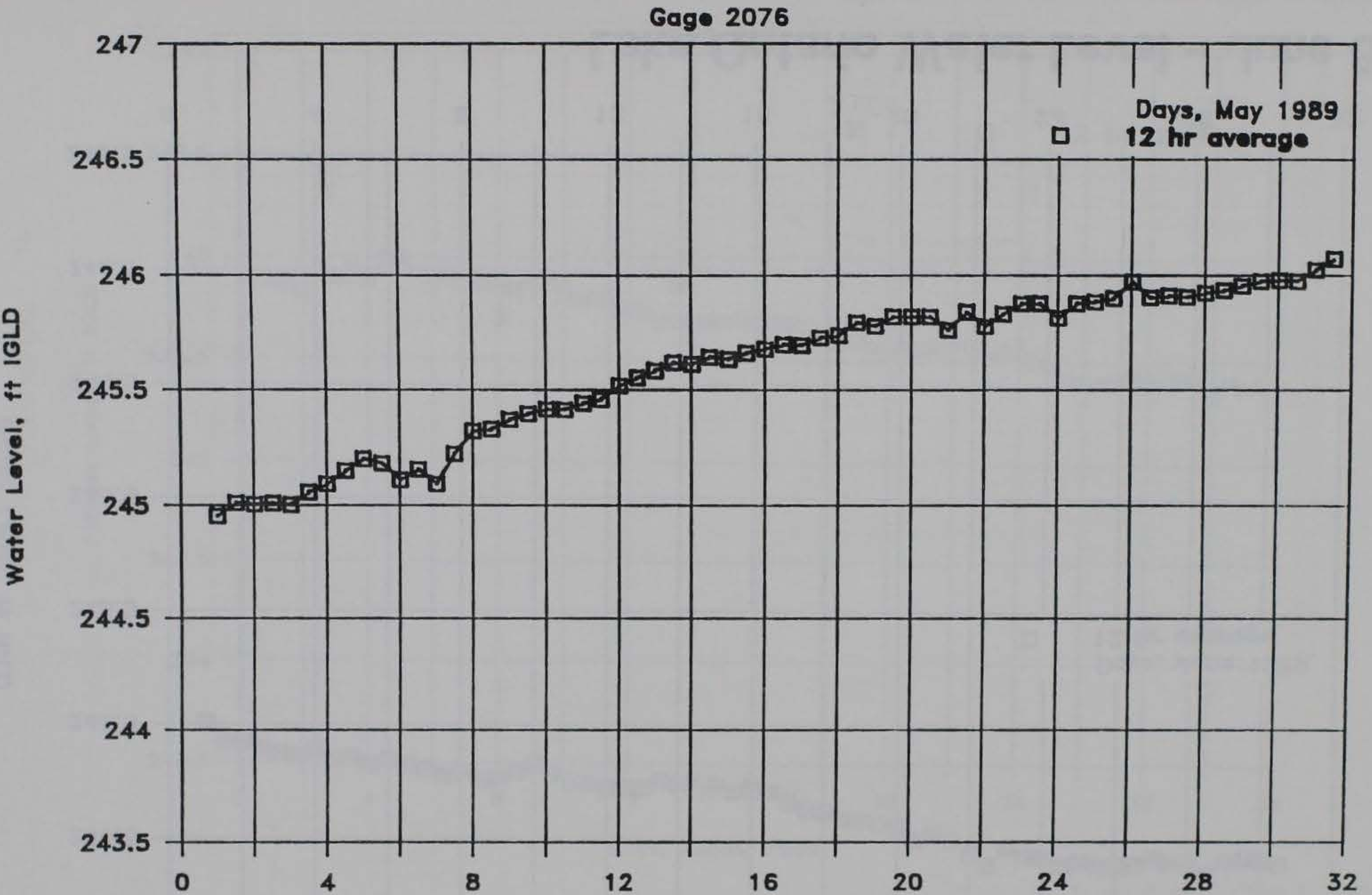


Creek Discharge
Surveys 7-12

PLATE 15

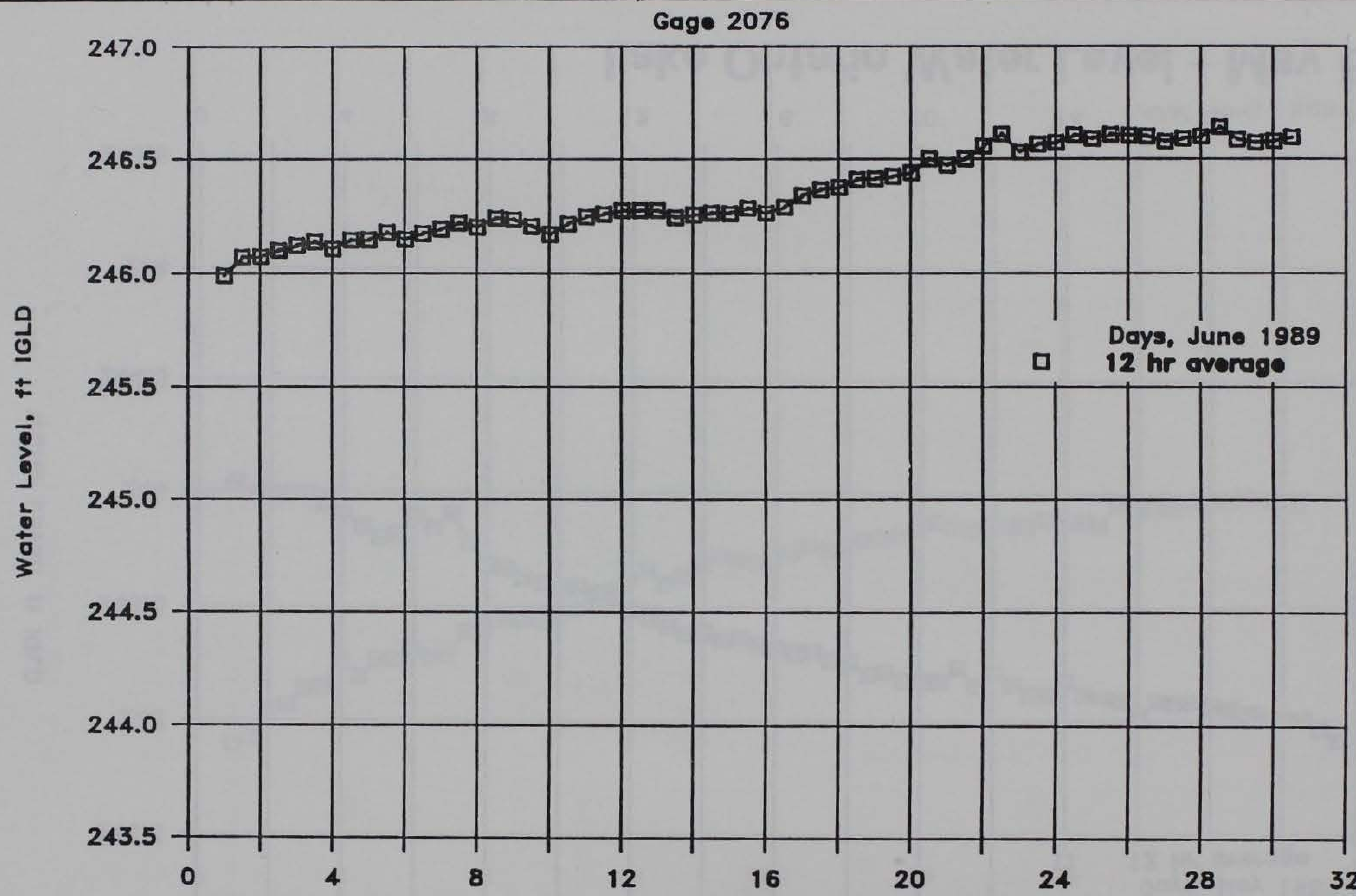


Lake Ontatio Water Level - April 89

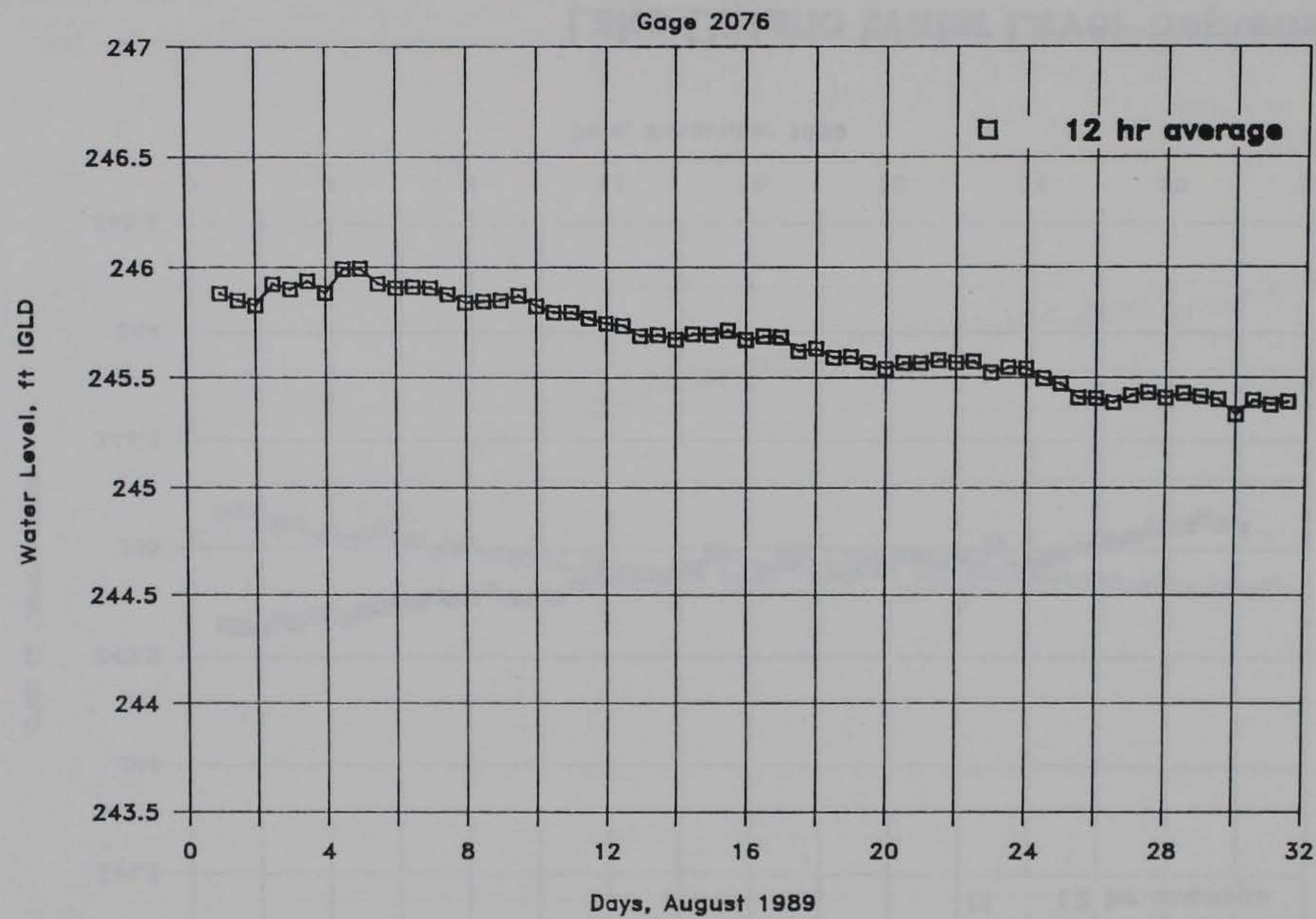


Lake Ontario Water Level - May 89

PLATE 18



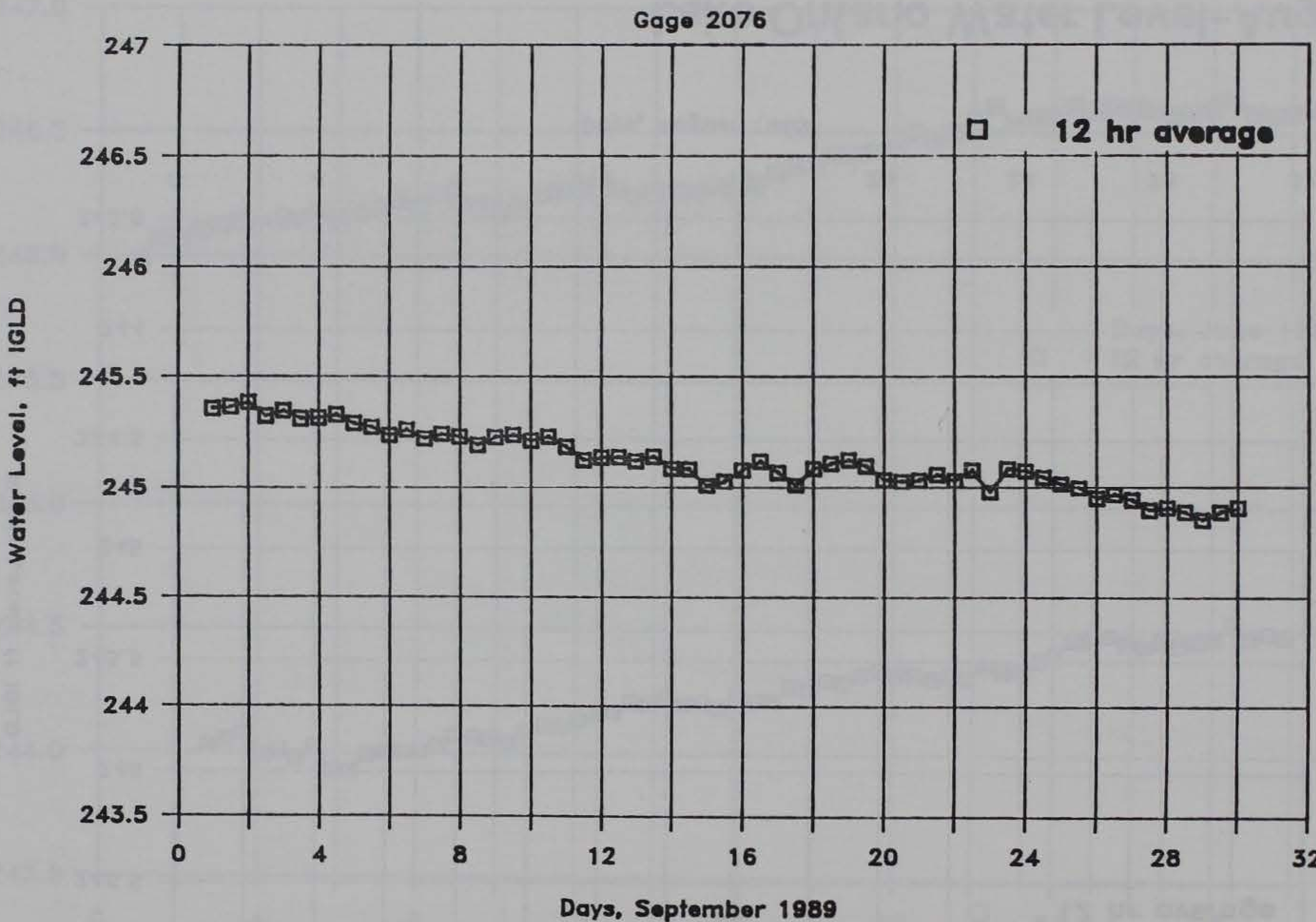
Lake Ontario Water Level - June 89



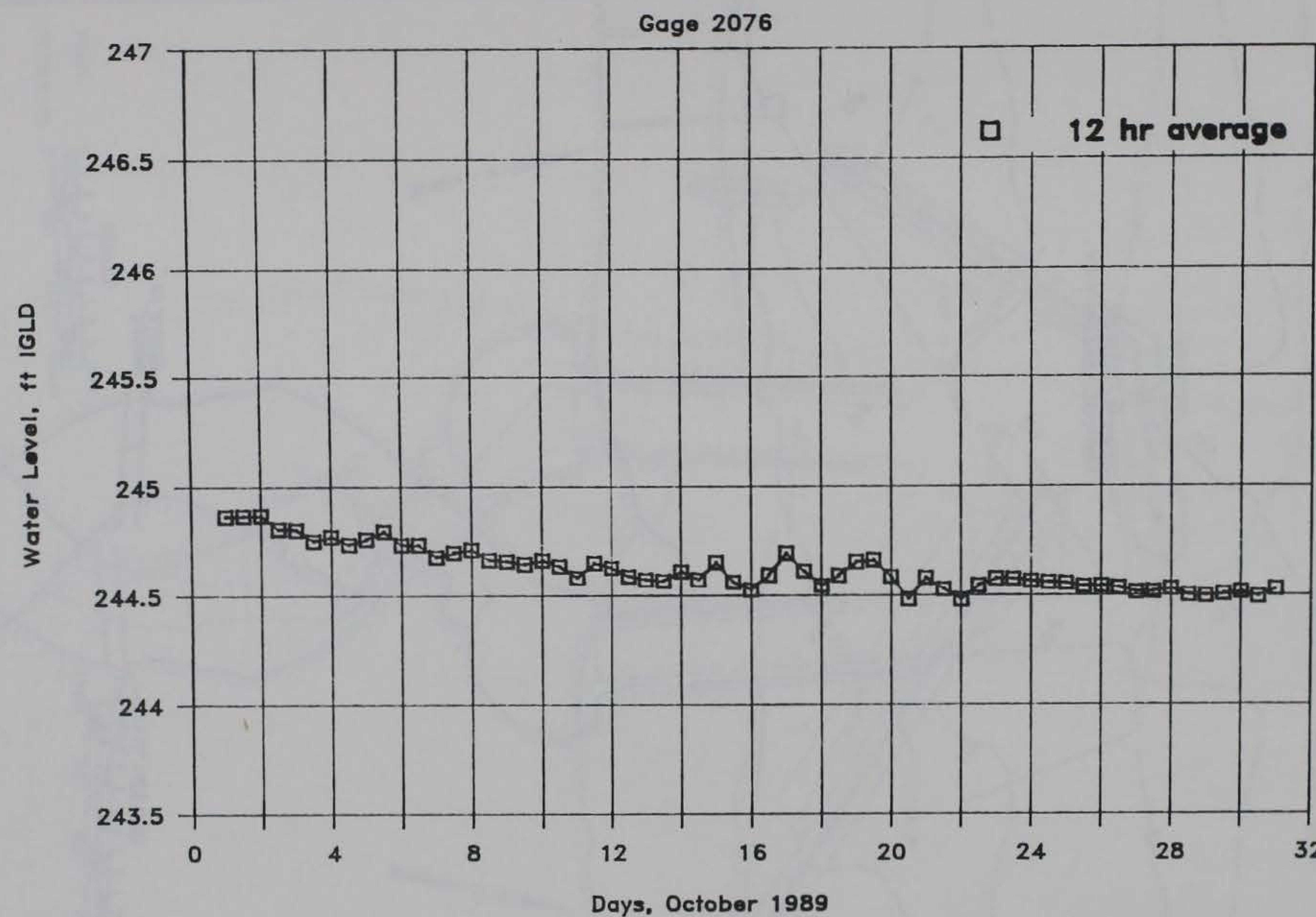
Lake Ontario Water Level–August 89

PLATE 19

PLATE 20

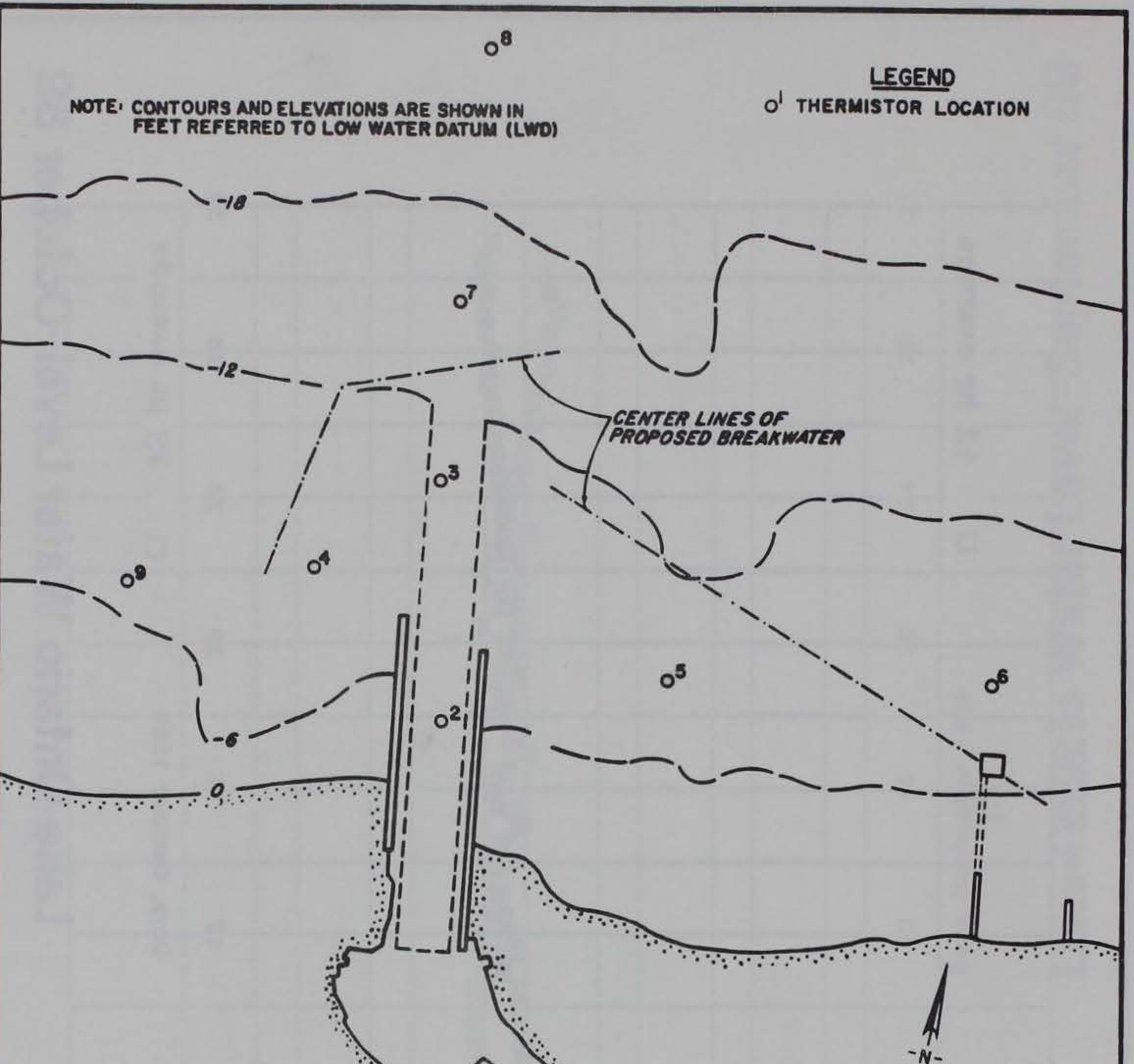


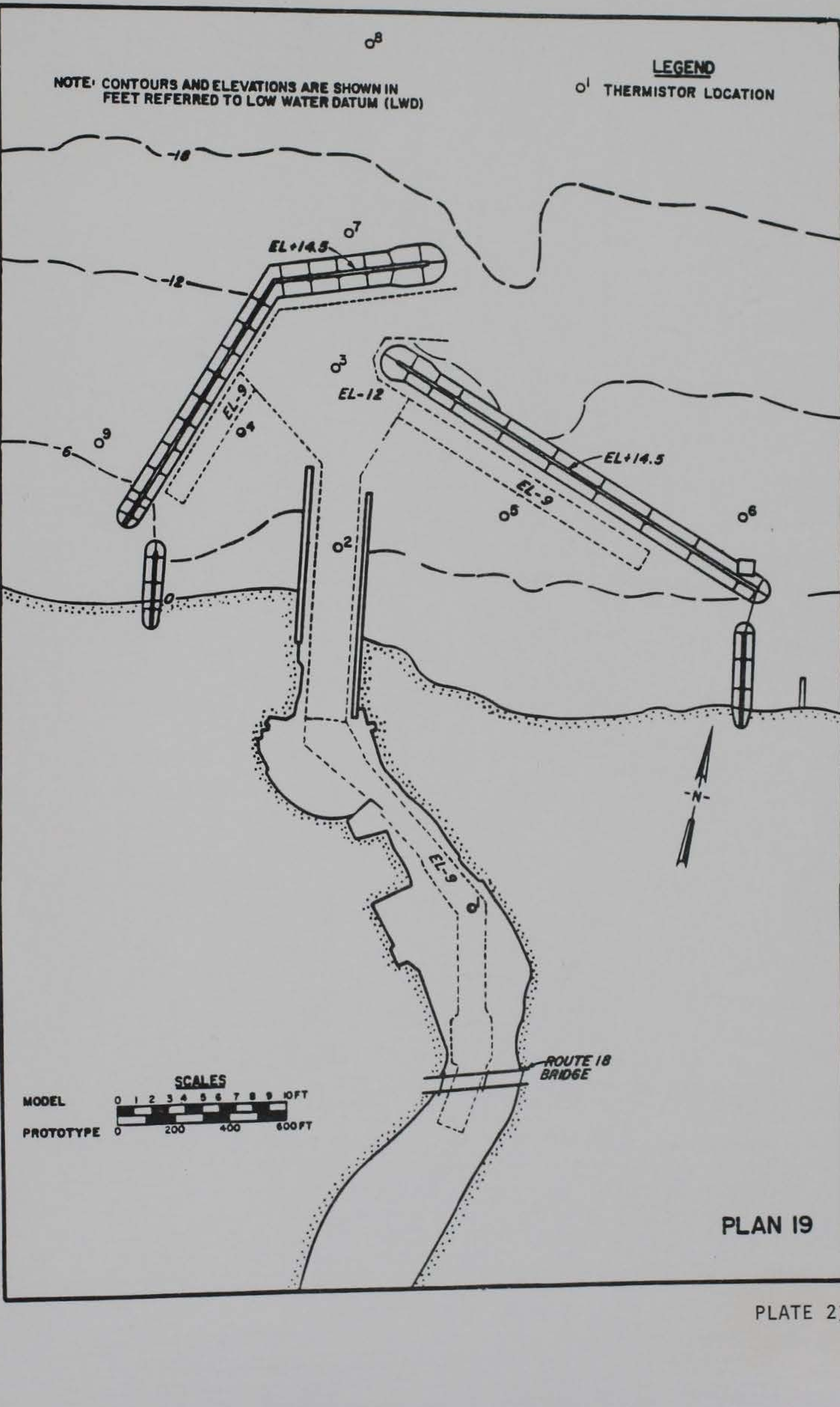
Lake Ontario Water Level–September 89



Lake Ontario Water Level-October 89

PLATE 21


NOTE: CONTOURS AND ELEVATIONS ARE SHOWN IN FEET REFERRED TO LOW WATER DATUM (LWD)
LEGEND
O1 THERMISTOR LOCATION
-18
-12
-6
0
CENTER LINES OF PROPOSED BREAKWATER
ROUTE 18 BRIDGE
N
SCALES
MODEL 0 1 2 3 4 5 6 7 8 9 10 FT
PROTOTYPE 0 200 400 600 FT
EXISTING CONDITIONS


NOTE: CONTOURS AND ELEVATIONS ARE SHOWN IN FEET REFERRED TO LOW WATER DATUM (LWD)
LEGEND
O1 THERMISTOR LOCATION
-18
-12
-6
EL+14.5
EL+14.5
EL-9
EL-12
EL-9
EL-9
ROUTE 18 BRIDGE
-N-
SCALES
MODEL 0 1 2 3 4 5 6 7 8 9 10 FT
PROTOTYPE 0 200 400 600 FT
PLAN 19