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Craver, Patti

From: Balsam, Briana (NRC)
Sent: Thursday, April 12, 2012 1:01 PM
To: Julie Crocker
Subject: RE: Pilgrim: NRC's complete responses to 4-9-12 NMFS questions
Attachments: Normandeau 1977.zip

Reference 3 of 4.

From: Balsam, Briana
Sent: Thursday, April 12, 2012 12:56 PM
To: 'Julie Crocker'
Cc: Logan, Dennis; Susco, Jeremy; Smith, Maxwell; 'jegan1@entergy.com'
Subject: Pilgrim: NRC's complete responses to 4-9-12 NMFS questions

Julie,

I attached the NRC's completed responses to the questions on Pilgrim that you sent in your April 9 email to follow-up on our partial response dated April 10.

I will also be forwarding several zip files containing the documents referenced in the responses in subsequent emails. I tried to send them all as one zip folder, but it seems as if my agency's email attachment size limit is a bit higher than yours—the last email I was able to send, but it came back undeliverable. All of the references should also be publically available in our ADAMS system also, and I have included the accession number for each in the attached responses, so that would be another way for you to access those documents if email doesn't work.

Briana

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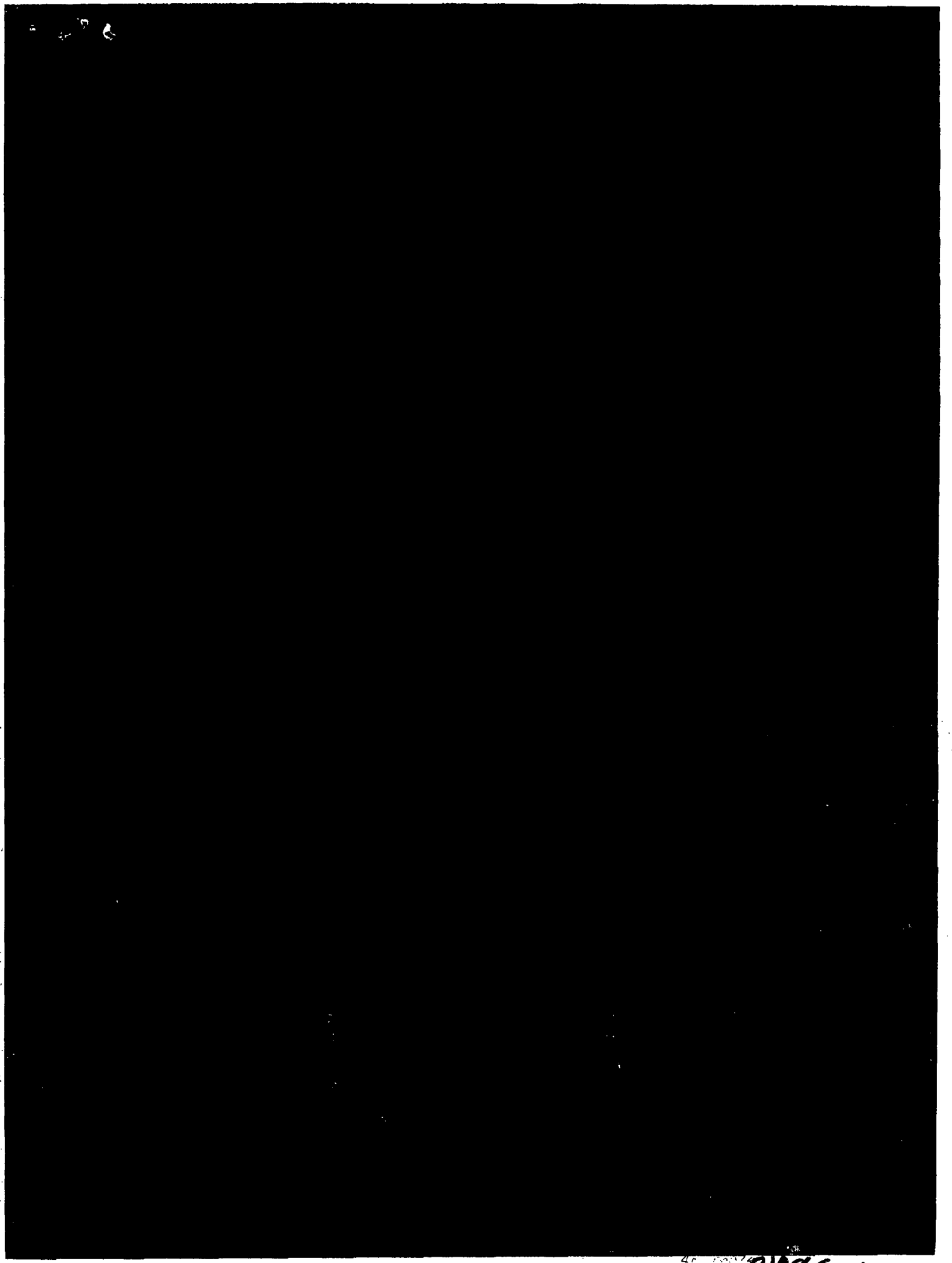

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THERMAL SURVEYS OF BACKWASHING OPERATIONS AT PILGRIM STATION DURING JULY 1977

Conducted for

BOSTON EDISON COMPANY
800 Boylston Street
Boston, Massachusetts 02199
under
Purchase Order No. 60107

by

NORMANDEAU ASSOCIATES, INC.
Bedford, New Hampshire 03102

August 1977

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1.0 ABSTRACT

Two weekend surveys of actual backwashing operations at Pilgrim Nuclear Power Station under varying tidal conditions were conducted by Normandeau Associates, Inc., during July 1977. These surveys documented the spatial extent of the thermal backwash plume within the intake area and out into Cape Cod Bay. For the first survey on July 9 and 10, 1977, backwashing began at low water and continued into early flood tide. For the second survey dated July 16 and 17, 1977, backwashing began at high water and continued into early ebb tide.

Backwashing formed a thermal plume about 5- to 6-ft thick (1.5 to 1.8 m) in front of the intake screenwall. Here, maximum surface temperatures of 100.9 F (38.3 C) were observed, representing a ΔT of 43.4 F (24.1 C) above ambient. The distal edge or frontal zone of the plume spread slowly seaward at about 0.2 kn; where it became thinner and rapidly lost heat by convection to the surrounding waters, dilution and ultimate release to the atmosphere. Along the intake shoreline the plume was often less than 1 ft (0.3 m) thick. Most of the hot water was dissipated within several hundred feet of the intake with ΔT's of 10 to 15 F (5.6 to 8.3 C) above ambient. Under the influence of strong southwesterly winds during the second survey, some hot water was apparently carried beyond the outer breakwaters into Cape Cod Bay. In summary, the backwashing operation caused a relatively thin thermal plume which spread rapidly across the western portion of the study area and along the outer breakwater. Within a few hours, it had completely dissipated.

The funding for this study was provided by Boston Edison Company. Technical and logistical support was provided by the Environmental Sciences Group of the Nuclear Engineering Department and the staff of the Security and Operations Departments at Pilgrim Station.

2.0 INTRODUCTION

2.1 STUDY AREA AND STATION CHARACTERISTICS

The Pilgrim Nuclear Power Station is located on the shore of Cape Cod Bay in Plymouth, Massachusetts, about 5.5 mi (8.9 km) east-southeast of the Town Center. The site, which is owned and operated by the Boston Edison Company, now contains a 655 MW light water moderated, boiling water nuclear reactor (Unit 1) with a once-through condenser cooling system. Water used for cooling the condenser is removed from Cape Cod Bay through a shoreline intake (Figure 2.1-1). It enters the intake between two breakwaters via a dredged channel which is about 18 to 24 ft deep (5.5 to 7.3 m) at mean low water (MLW).

Under normal operating conditions, the water is drawn into the intake by two pumps, circulated through the condenser system and discharged to a surface canal at a rate of about 510 million gallons/day and a ΔT (difference between the discharge and intake temperatures) averaging 30.0 F (16.7 C). Unit 1 has a circulating water flow of 690 ft^3/sec (cfs) at a maximum temperature rise of 30.0 F (16.7 C) and a service water flow of 23 cfs at a maximum temperature rise of 15 F or 8.3 C (Stone and Webster, 1975). The Unit 1 screenwell contains two circulating water pumps whose water supply passes under the skimmer wall. Its bottom is about 7.5 ft (2.3 m) below MLW at the front of the intake structure.

Condenser tubes on Unit 1 can be cleaned by backwashing on a 1-to 2-week interval, depending upon biofouling severity. Generally 45 to 60 min is required to treat each of the two circulating water pumps, with elevated temperatures averaging around 100 F (37.8 C). Occasionally the temperatures peak at from 110 F (43.3 C) to 120 F (48.9 C) depending upon the amount of heat treating necessary. Because plant load must be reduced during backwashing, the operation is generally conducted during off-peak hours late Saturday night and early Sunday morning.

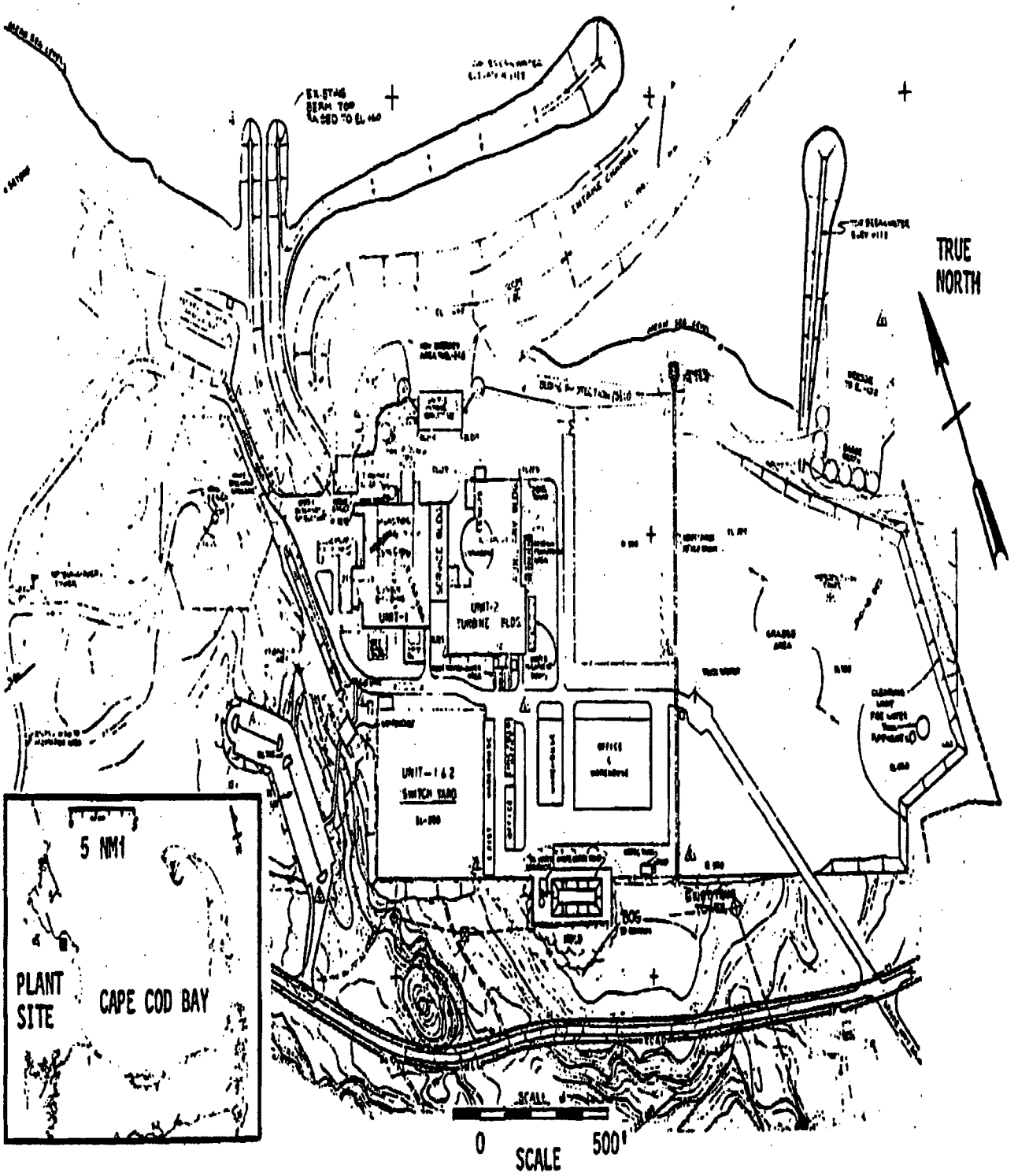

Figure 2.1-1. Location map showing Pilgrim Nuclear Power Station Unit 1 and Unit 2 (Proposed) and adjacent coastal waters. Pilgrim Station Backwashing Studies, 1977.

2.2 THERMAL SURVEYS

Normandeau Associates, Inc. (NAI) was contracted by Boston Edison Company to conduct two thermal surveys of actual backwashing operations during mid summer when ambient water temperatures were at or approximately their annual peaks (NAI, 1977). The purpose of the surveys was to determine the spatial extent in the waters between the two breakwaters and out into Cape Cod Bay of the resulting backwash plume under varying tidal conditions. It was desired to avoid periods of spring tides when tide ranges are higher than average and periods of neap tides when tide ranges are lower than average. In addition, the surveys were to avoid stormy weather when waves, currents and winds could upset normal backwashing plume dissipative processes (a conservative approach).

Two separate thermal surveys were conducted. The first was July 9 and 10, 1977, during which the backwashing operation began at low water. One week later on July 16 and 17, 1977, the second survey was conducted with backwashing beginning at high water. During both surveys, emphasis was placed on examining the time history of plume build-up and dissipation.

3.0 METHODS OF STUDY

3.1 FIELD SURVEYS

Thermal surveys of actual plant backwashing operations were conducted overnight during July 9 and 10, 1977 (low-water backwash) as well as July 16 and 17, 1977 (high-water backwash). The surveys consisted of the following:

3.1.1 TEMPERATURE PROFILING

During both nights a series of four basic thermal surveys were conducted throughout the entire study area. Approximate sampling locations for July 9 to 10, 1977 are shown in Figure 3.1-1. Sampling locations for July 16 to 17, 1977 are shown in Figure 3.1-2. Actual sampling stations for specific surveys are indicated in the respective figures in Section 4.0. Each survey was conducted as rapidly as possible to provide quasisynoptic temperature distributions in the study area.

At each given station depth-temperature profiles were obtained with an NAI Model 3100-TD profiling system. Data were directly recorded on a Houston Instruments Model 2000 X-Y recorder. The rapid response time of the system allowed complete profiles to be obtained from surface to bottom at each station over a 30-to 45- sec period. Instrumentation specifications are given in Table 3.1-1. Actual plots were field annotated as to station number, time (Eastern Standard was used throughout) and range distances to navigational transponders. Precision location data for each station were obtained with a Motorola Mini-Ranger III and onboard printer using two transponders placed on shore. One transponder was located at the east end of a footbridge over the discharge canal; the other was located on top of the seawall near the old barge landing site (Figures 3.1-1 and 3.1-2).

Supplemental temperature profiles were obtained each night from small boats anchored along the axis of the dredged intake channel

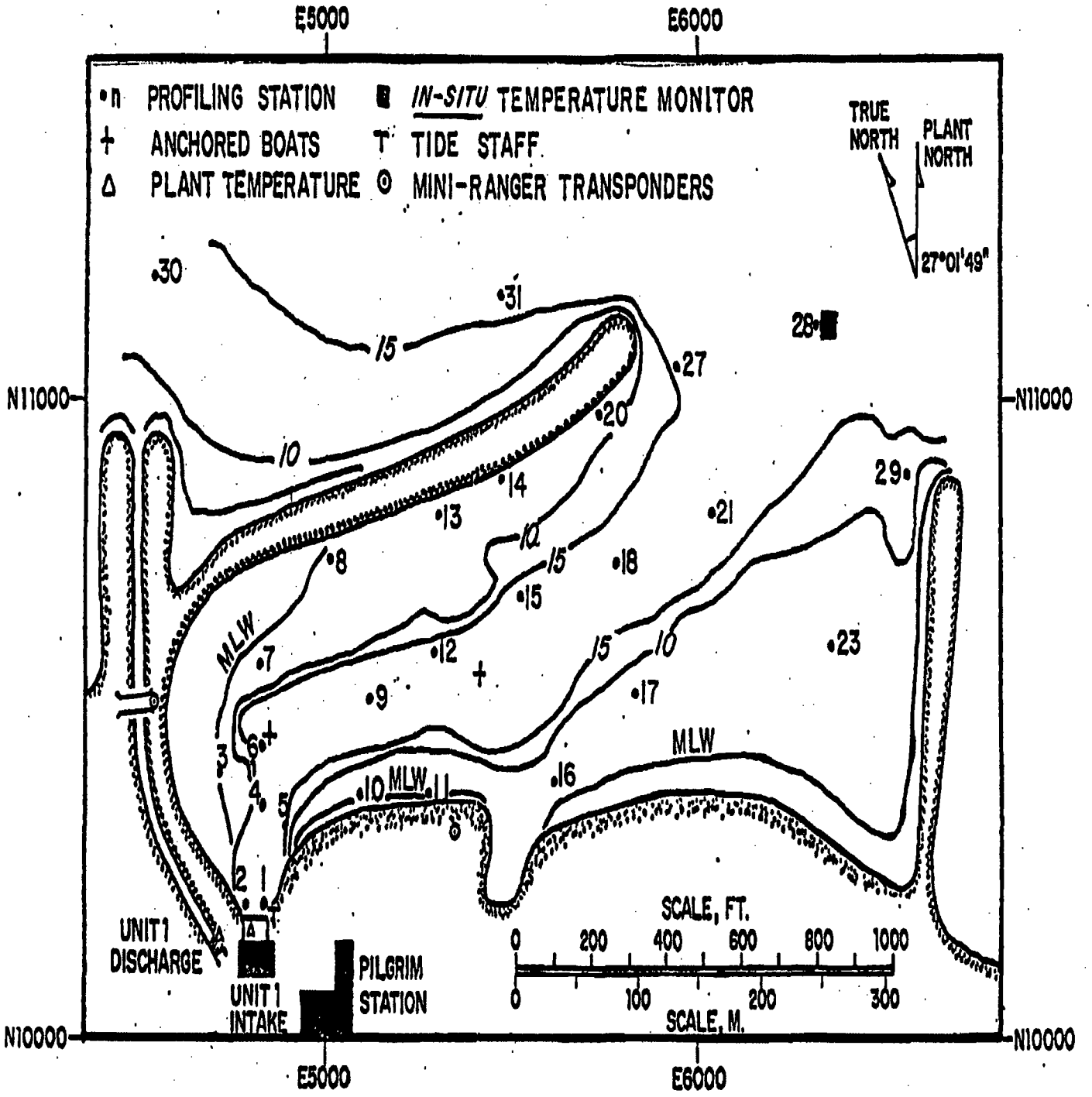

Figure 3.1-1. Location map showing approximate sampling stations and *in-situ* instrumentation for the backwash survey of July 9 and 10, 1977. Pilgrim Station Backwashing Studies, 1977.

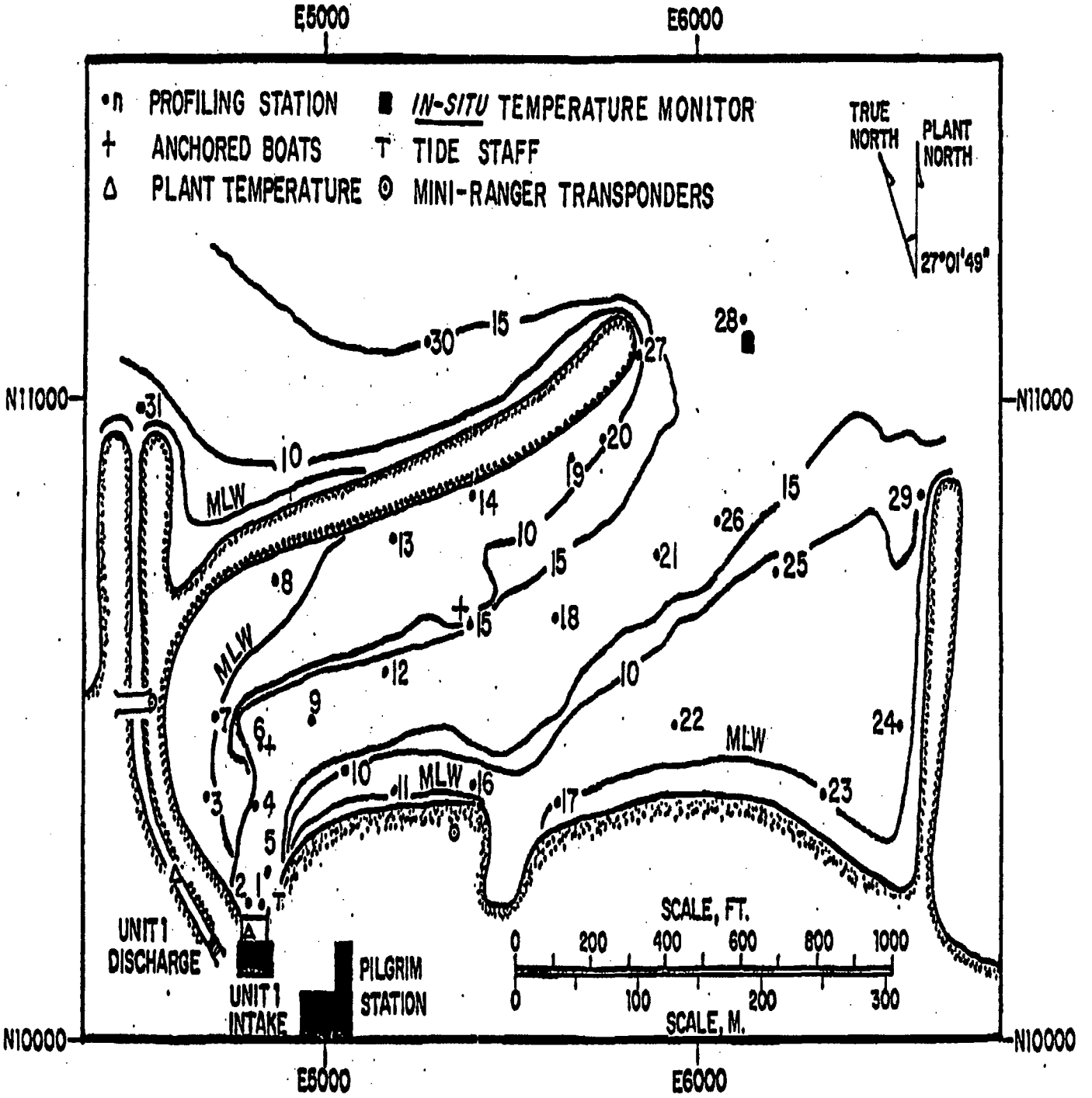

Figure 3.1-2. Location map showing approximate sampling stations and *in-situ* instrumentation for the backwash survey of July 16 and 17, 1977. Pilgrim Station Backwashing Studies, 1977.

TABLE 3.1-1. SPECIFICATIONS FOR INSTRUMENTATION UTILIZED IN THE NAI THERMAL SURVEYS AT PILGRIM STATION. PILGRIM STATION BACKWASHING STUDIES, 1977.

MANUFACTURER	MODEL	PARAMETER MEASURED	TYPE OF SENSOR	MEASUREMENT THRESHOLD	RANGE	ACCURACY	RECORDING			REMARKS
							MEDIUM	SAMPLING PERIOD	SAMPLING FORMAT	
CURRENT VELOCITY										
Bendix	Q-15	Speed	Ducted Impeller	0.04 kns	0 to 1 kns 0 to 5 kns switch selectable	± 3% or ± 0.05 kns whichever is greater	Strip chart	14 days	Continuous	Rustrak Model 291 DC recorder
	Current Sensor and 270 Recorder	Direction	Vane with potentiometric direction transducer and compass		0° to 360°	± 12°	Strip chart	14 days	Continuous	
		Time	Bulova Model YB-11 Accutron Cycle Timer	N/A	N/A	± 2 sec/day		14 days	3-hr cycling switch	3-hr event marks
TEMPERATURE										
NAI	In site Temperature Monitor	Temperature	Rustrak Model 1332 Thermistor		30 to 80 F 70 to 130 F	± 1.0 F or ± 0.46 C	Strip chart	14 days	Continuous	Rustrak Model 2133 DC recorder
		Time	Bulova Model YB-11 Accutron Cycle Timer	N/A	N/A	± 2 sec/day		14 days	3-hr cycling switch	3-hr event marks
NAI	Model 3100-TD Profiling System	Temperature	Rosemount Model 171CD Platinum Resistance Temperature Sensor	N/A	0 to 40C	± 0.05C	Digital Display	N/A	Continuous	Manual Reading
		Depth	NAI Pressure Transducer	N/A	0 to 50 ft	± 0.1 ft	X - Y Plot	N/A	Continuous	Houston Inst. Model 2000 X-Y Recorder
NAI	Model 631 Digital Thermometer	Temperature	YSI Model 44033 Thermistor	N/A	0 to 50C	± 0.25C	Digital Display	N/A	Continuous	Manual Reading
LOCATION										
Motorola	Mini-Ranger III	Location	Electronic Receiver-transponder system	N/A	0 to 20 MIC	± 3m	Digital Display and printer	N/A	Continuous	Manual Reading and Printing

(Figures 3.1-1 and 3.1-2). Observers in each boat used NAI Model 631 digital thermometers to obtain profiles from surface to bottom every 10 min. In general, sampling depths were surface, 1.6 ft (0.5 m), 3.3 ft (1.0 m), and thereafter every 3.3 ft (1.0 m) to bottom. Data were recorded on NAI Form PS-121, Physical Sciences Hydrographic Data Sheet, in accord with NAI Physical Sciences Data Processing Technical Procedures Manual 5.0 (NAI, 1976a).

During mobilization prior to the surveys and demobilization following the surveys, all of the instruments were calibrated as appropriate in accord with NAI Technical Procedures Manual 3.0 (NAI, 1976b) Supplemental reference checks were made for each temperature instrument in the field prior to the surveys using a large barrel of sea water and precision grade mercury thermometers. All calibration data and supporting paperwork were reviewed and audited independently by NAI's Quality Assurance Director in accord with Company procedures and Technical Procedures Manuals (NAI, 1976c).

Data were processed as shown in Figure 3.1-3. Once field data were keypunched, listed, edited and verified, observed temperatures were transformed to true temperatures by means of appropriate regression equations from calibration data for each respective field instrument. Finally using measurements from ambient near-bottom waters at Station 28 (mid channel between the two breakwaters as in Figures 3.1-1 and 3.1-2), a delta-T or approximate temperature rise above ambient was calculated for each temperature measurement. For ease in report preparation, the computer converted all depth data to both ft and m and temperature data to both F and C, regardless of which units were originally input.

3.1.2 CURRENT PROFILING

At selected stations during both surveys (Figures 3.1-1 and 3.1-2) current profiles were obtained from near surface to near bottom using Bendix Model Q-15 ducted impeller current meters and Model 270 recorders. During mobilization prior to the surveys and demobilization

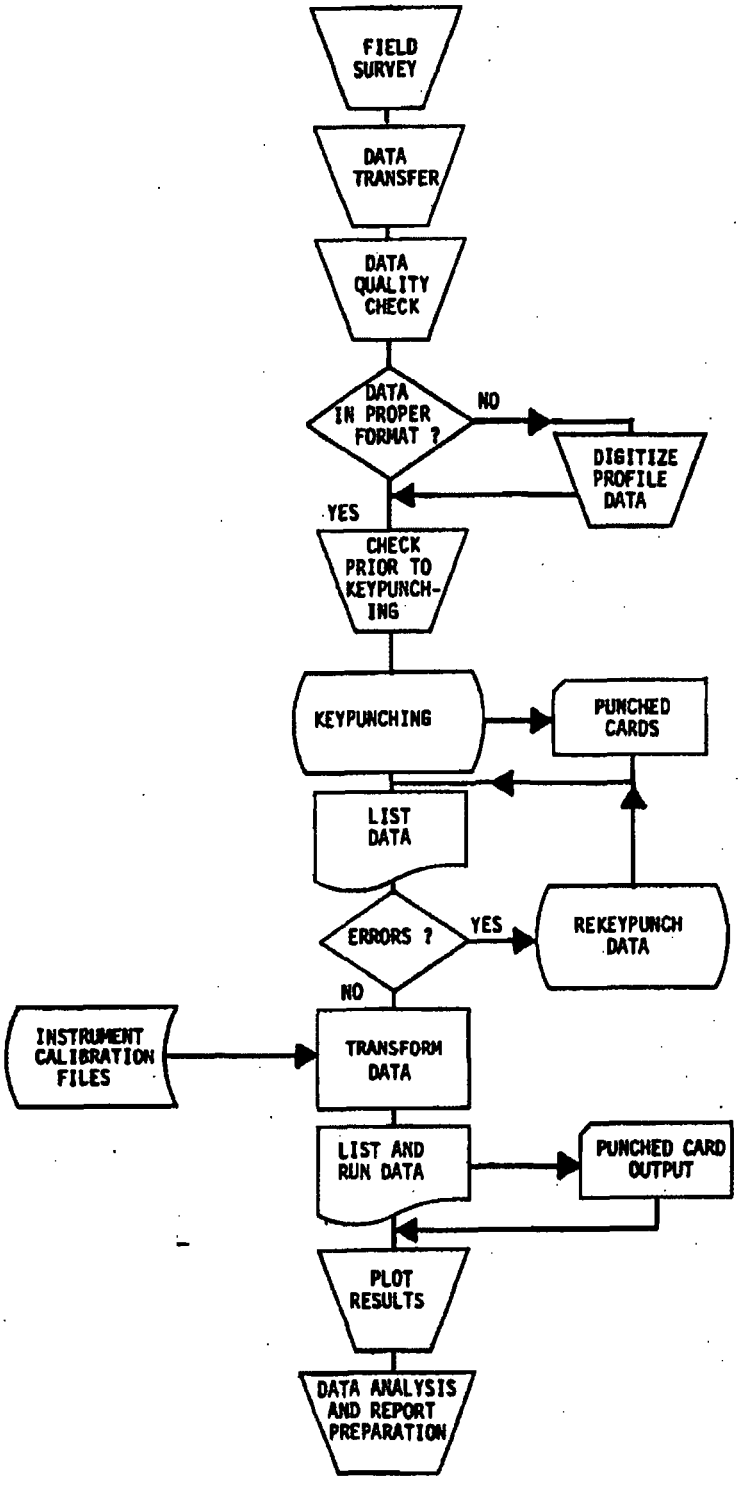

Figure 3.1-3. Flow chart for processing thermal survey data. Pilgrim Station Backwashing Studies, 1977.

following the surveys, all of the instruments were calibrated as appropriate in accord with NAI Technical Procedures Manual 3.0 (NAI, 1976 b). Supplemental reference checks were made in the field prior to the surveys. Complete instrumentation specifications are given in Table 3.1-1.

Data were recorded on strip charts and annotated as appropriate along with visual observations of ambient wind conditions and flow patterns. The primary survey vessel collected data from a number of mid-channel stations. The small boat anchored closest to the intake near Station 6 collected data from various depths at a single location. The strip charts were manually time based and reduced. Directional data were converted to degrees true (referenced toward which the current was flowing) and depicted vectorially.

3.1.3 CONTINUOUS TEMPERATURE MONITORING

During each overnight survey an *in-situ* NAI temperature monitor was deployed about 3.3 ft (1.0 m) above the bottom at Station 28. Its purpose was to obtain continuous ambient temperature data from waters which would be unaffected by backwashing operations.

A second NAI temperature monitor was deployed at the plant. One thermistor was positioned about 3.3 ft (1.0 m) below a styrofoam float inside the waterbox of the west circulating water pump. It was set for a range of 70 to 120 F (21.1 to 48.9 C) to document actual times and temperatures of backwashing. The other thermistor was attached to concrete blocks and submerged in the discharge canal. It was set for a range of 50 to 120 F (10.0 to 37.8 C) to document normal plant discharge temperatures in real time. Both channels of data were input to a Rustrak Model 2133 DC strip-chart recorder with a time sharing feature for maximum data resolution.

Actual deployment locations for these temperature monitors are shown in Figures 3.1-1 and 3.1-2. Instrumentation specifications are given in Table 3.1-1. During mobilization prior to the surveys and de-

mobilization following the surveys, all of the instruments were calibrated as appropriate in accord with NAI Technical Procedures Manual 3.0 (NAI, 1976b).

Data were recorded on strip charts. The strip charts were manually time based using start times, 3-hr timer marks, and end times. Data were manually reduced to obtain readings every 10 min.

3.1.4 TIDE OBSERVATIONS

During both surveys visual observations of tide elevation at the intake screen wall were made using the large tide staff located beside the plant access ladder (Figures 3.1-1 and 3.1-2). In general, readings were made each time Station 1 was occupied. Resulting data were plotted to the same scale as the National Oceanic and Atmospheric Administration - National Ocean Survey tide predictions (NOAA-NOS, 1977).

3.1.5 WIND AND AIR TEMPERATURE OBSERVATIONS

During both surveys visual observations of wind conditions and periodic readings of air temperature were made from the main survey vessel. Hourly average measurements of wind speed, wind direction and air temperature from the 33-ft (10-m) level at the 160 ft (48.8 m) meteorological tower east of Pilgrim Station (Figure 2.1-1) were obtained from Boston Edison Company.

3.2 PLANT OPERATIONS

The plant backwashing operation was scheduled to begin at either low water (July 9 and 10) or at high water (July 16 and 17). Backwashing is accomplished by operating a single circulating water pump, completely closing the discharge valves at each outlet water box, and operating the crossover valve connecting the discharge water boxes.

Circulating water will flow naturally through one side of the condenser, cross over, and flow in the reverse direction through the other side, discharging back to the intake structure through the idle circulating water pump. Generally, 45 to 60 min is required to treat each side of the condenser. Plant temperature measurements and operational data from the backwashing were obtained from Boston Edison Company.

4.0 RESULTS

4.1 JULY 9 AND 10 LOW-WATER BACKWASH SURVEY

4.1.1 PLANT OPERATION

This backwash survey consisted of five sampling runs keyed to actual plant operations (Table 4.1-1 and Figure 4.1-1). First, plant load was gradually brought down, resulting in temperatures in the discharge canal decreasing from 87 F (30.6 C) to 74.6 F (23.6 C). Next, Pump B (west) associated with water boxes 1-2 and 1-4, was backwashed from about 0030 to 0119 EST. The *in-situ* temperature monitors recorded a sudden sharp rise in discharge temperature to about 83 F (28.3 C) then a sharp drop to about 65.3 F (18.5 C). Simultaneously, water box temperatures rose sharply to about 104 F (40.0 C) and were sustained for much of the backwashing period. As backwashing of Pump B neared completion, discharge temperatures rose again to 83.2 F (28.4 C) and water box temperatures dropped back down to below 70 F (21.1 C). From about 0150 to 0227 EST Pump A (east) associated with water boxes 1-1 and 1-3 was backwashed in a similar manner with backwash temperatures about the same for both pumps. During this backwashing, discharge temperatures dropped to about 70.6 F (21.4 C), then rose to 87 F (30.6 C) for a short time, dropped back down to about 75 F (23.9 C), and then gradually started to rise back toward normal operational levels (Figure 4.1-1).

4.1.2 AMBIENT TEMPERATURE

In any study of power plant thermal effects, many different approaches can be taken to define what "ambient" temperature (temperature of surrounding waters that are essentially unaffected by the plant) actually is. For example, one could use seasonal mean temperatures, monthly mean temperatures, weekly mean temperatures, daily mean temperatures, or even hourly mean temperatures from whatever location and depth deemed appropriate. The rationale for determining ambient temperature for this and the subsequent

TABLE 4.1-1. SAMPLING RUNS AND AMBIENT BASE TEMPERATURES FROM STATION 28 FOR THE JULY 9 AND 10, 1977 LOW-WATER BACKWASH SURVEY.

SAMPLING RUN	TIDE STAGE	(PLANT STATUS)	SAMPLING INTERVAL; EST	AMBIENT BASE TEMPERATURE		AMBIENT TEMPERATURE RANGE MAXIMUM		MINIMUM	
				F	C	F	C	F	C
1	Late ebb	(Pre-backwash)	2140 to 0038	52.0	11.1	58.0	14.3	49.0	9.4
2	Early flood	(Backwash West Pump)	0039 to 0203	57.2	14.0	57.9	14.4	56.0	13.3
3	Mid flood	(Backwash East Pump)	0204 to 0309	57.6	14.2	59.0	15.0	57.0	13.9
4	Late flood	(Post backwash)	0310 to 0415	60.3	15.7	60.5	15.8	59.6	15.3
5	Late flood	(Survey complete)	0416 to 0430	60.3	15.7	60.4	15.7	60.2	15.6

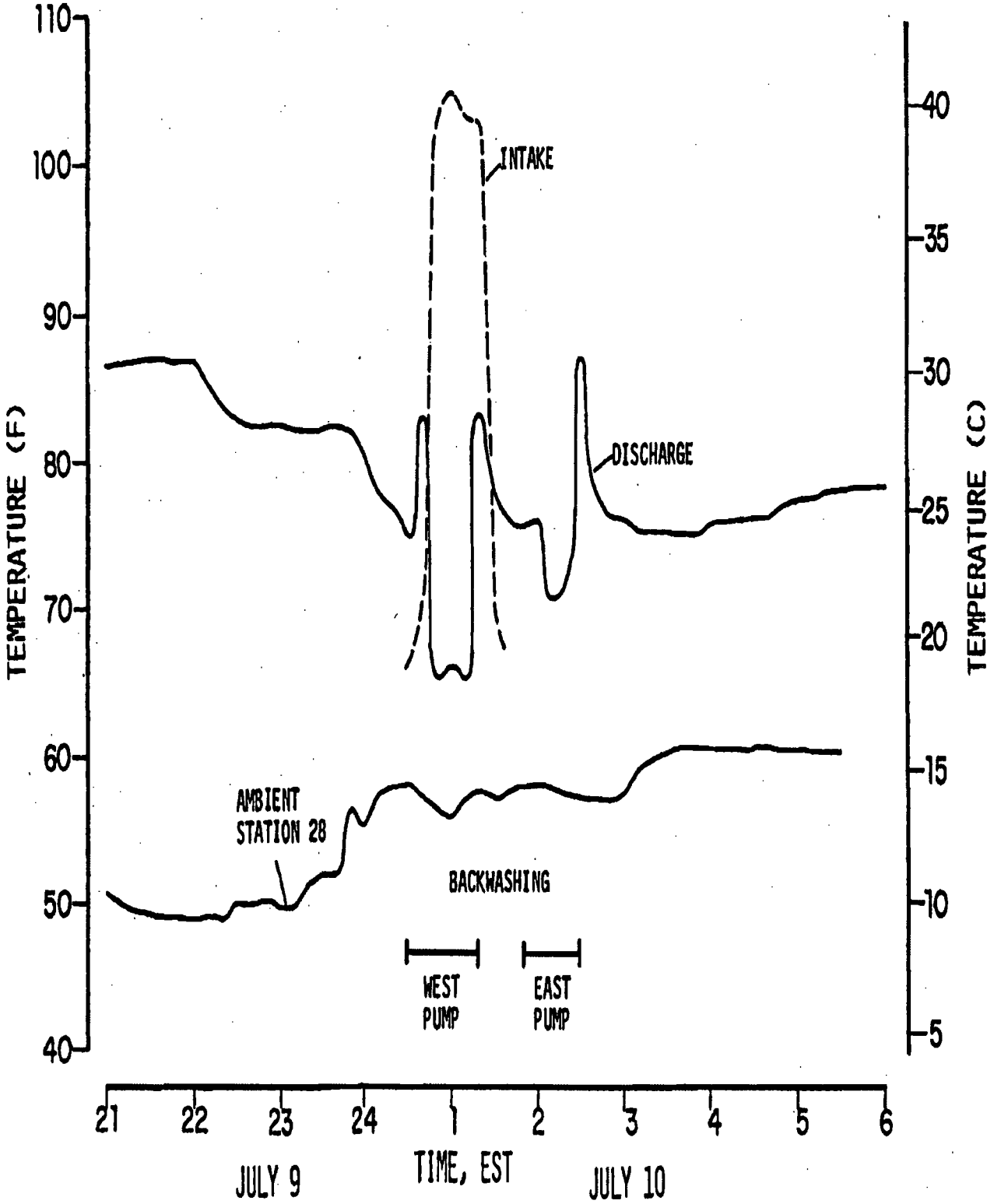

Figure 4.1-1. Temperature monitor data from the west pump waterbox, the discharge canal and the ambient *in-situ* unit at Station 28 during backwashing operations on July 9 and 10, 1977. Pilgrim Station Backwashing Studies, 1977.

July 16 and 17 survey was as follows: First an area which was well away from the intake but close enough to still be source water for the power plant intake was selected. It had to be an area which presumably would not be influenced by either backwashing or the discharge plume. Accordingly Station 28 in the middle of the dredged channel between the ends of the breakwaters was selected (Figure 3.1-1). Here an *in-situ* temperature monitor was deployed at about 3 ft (0.9 m) above the bottom in order to obtain a continuous temperature record throughout the survey. Data taken for the duration of each run were averaged to obtain an ambient base temperature for that run (Table 4.1-1). This ambient base temperature was used as an input to the computer and the resulting ΔT above or below ambient at each sampling point was calculated.

For this survey the ambient temperature started around 49 to 50 F (9.4 to 10. C). The ambient temperatures increased to about 58 F (14.4 C) around low water at 0030 EST (Figure 4.1-1). Throughout the rest of the night, ambient temperatures continued to rise slowly, reaching about 60 F (15.6 C) by the end of the survey. This rise may represent some recirculation of the discharge plume toward the intake area in response to local winds and coastal currents.

4.1.3 THERMAL SURVEYS

4.1.3.1 Late Ebb (Prebackwash) - 2140 to 0038 EST

The prebackwash survey during late-ebb was conducted from 2140 EST on July 9 through 0038 EST on July 10, 1977. Once all stations had been sampled, the survey boat returned to Station 1 at the intake and awaited start of backwashing. Surface temperatures showed rises (ΔT) above ambient (52.0 F or 11.1 C) ranging from 9.1 F (4.1 C) near the discharge to 4.9 F (2.7 C) at Station 3 (Figure 4.1-2). Apparently the main part of the discharge plume missed Station 30. Note that this figure (and all subsequent ones like it) shows the configuration of the shoreline in front of the plant, the breakwaters which form the intake area and the approximate limits of water at each of the various sampling depths.

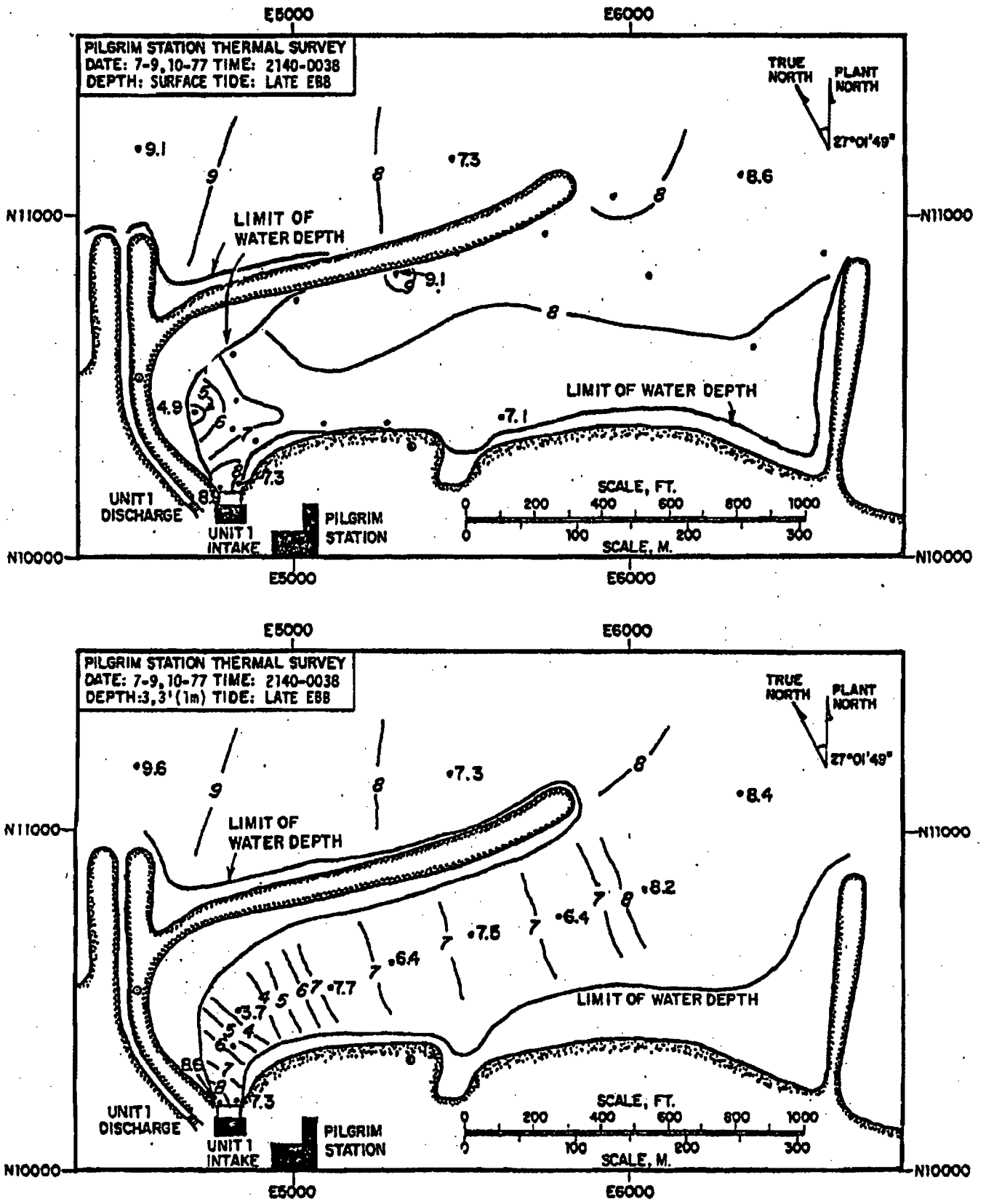

Figure 4.1-2. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during late ebb (pre-backwash) at surface and 3.3 ft (1.0 m) on July 9 and 10, 1977. Pilgrim Station Backwashing Studies, 1977.

Slightly deeper at 3.3 ft (1.0 m), ΔT's ranged from 9.6 F (5.3 C) near the discharge to 3.7 F (2.1 C) at Station 6 (Figure 4.1-2). At 9.8 ft (3.0 m) ΔT's were 6.8 and 7.5 F (3.8 and 14.2 C) due to drawdown at the intake; ΔT's ranged from 0.5 to 5.3 F (0.3 to 2.9 C) along the dredged channel, and ranged from 5.9 to 8.4 F (3.3 to 4.7 C) outside the breakwaters (Figure 4.1-3). At the bottom, temperature ΔT's were 3.4 to 4.6 F (1.9 to 2.6 C) at the intake, but were 0 or negative along the channel. Note that 0 or negative ΔT's are always shown with a dot pattern. Outside the breakwaters they ranged from 1.0 to 6.1 F (0.6 to 3.4 C).

Consistent with the survey vessel data, measurements at Station 6 (Figure 3.1-1) showed the surface ΔT's of 9.3 F (5.2 C), gradually dropping to 7.5 F (4.2 C). These ΔT's corresponded to actual temperatures of 61.2 F (16.2 C) and 59.5 F (15.3 C) respectively (Figure 4.1-4). Near-bottom temperatures started with a ΔT of 2.7 F (1.5 C) and then became negative, corresponding to actual temperatures of 54.6 F (12.6 C) down to 51.8 F (11.0 C).

Further away from the intake at Station 15 (Figure 3.1-1) a similar pattern was observed (Figure 4.1-5). Surface ΔT's went from 8.5 to 6.4 F (4.7 to 3.6 C), corresponding to actual temperatures of 60.5 to 58.7 F (15.8 to 14.8 C). Along the bottom the ΔT's were all negative (down to 2.0 F or 1.1 C), corresponding to actual temperatures of 49.8 to 53.0 F (9.9 to 11.7 C).

4.1.3.2 Early Flood (Backwash West Pump)-0039 to 0203 EST

At about 0030 EST backwashing started on the west circulating water pump. The first visible evidence was a sudden rush of hot, turbulent water whose presence was marked by foam and a steamy vapor right in front of the intake. As the backwashing progressed, the hot water formed a surface layer about 5 ft (1.5 m) thick in front of the intake screenwall, reaching temperatures as high as 100 F (37.8 C). This layer formed a distinct frontal zone with ambient Cape Cod Bay waters. The frontal zone moved slowly as a concentric ring northward (or seaward) away from the

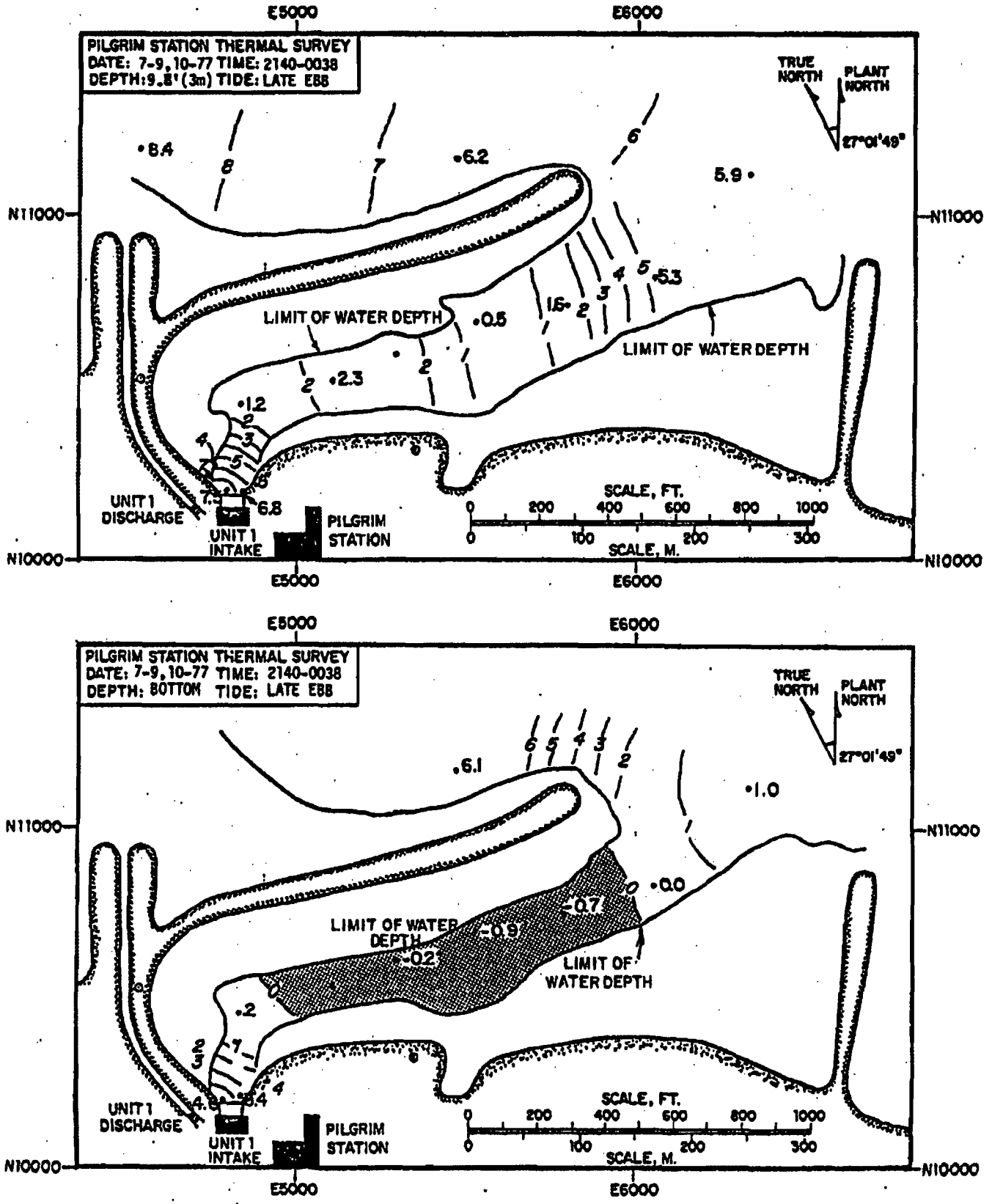

Figure 4.1-3. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during late ebb (preback-wash) at 9.8 ft (3.0 m) and bottom on July 9 and 10, 1977. Pilgrim Station Backwashing Studies, 1977.

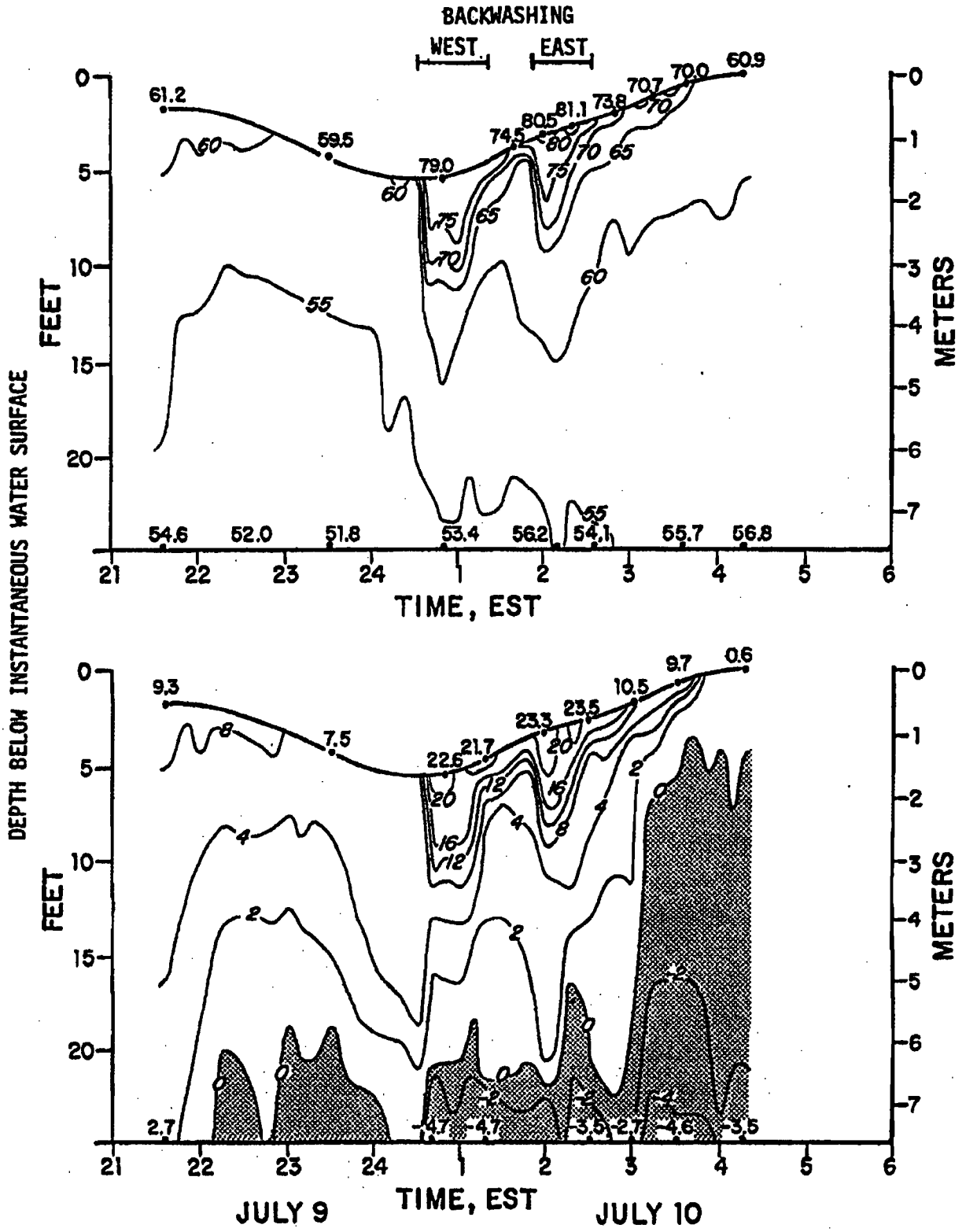

Figure 4.1-4. Temperature data from an anchored survey boat at Station 6 on July 9 and 10, 1977 showing actual temperatures and corresponding ΔT's above ambient in degrees F. Pilgrim Station Backwashing Studies, 1977.

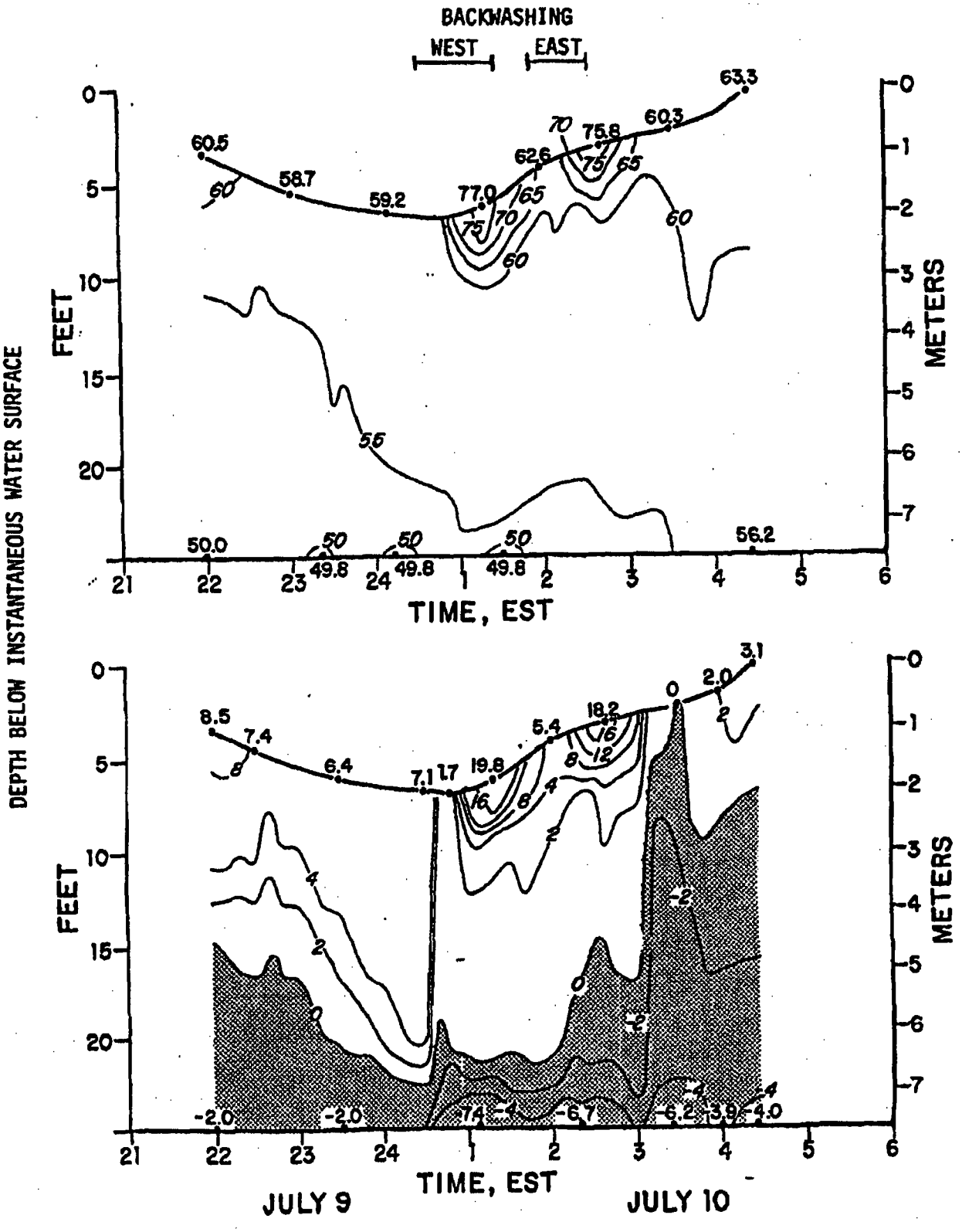

Figure 4.1-5. Temperature data from an anchored survey boat at Station 15 on July 9 and 10, 1977 showing actual temperatures and corresponding ΔT's above ambient in degrees F. Pilgrim Station Backwashing Studies, 1977.

intake, bulging in the middle and slightly restrained along shore due to frictional effects. The water temperatures in the near-surface thermal plume gradually decreased with distance away from intake and time, due to evaporative heat loss and dilution (mixing with ambient waters).

At the surface, ΔT's of 42.1 F (23.4 C) in front of the west pump and 24.8 F (13.8 C) in front of the east pump were observed (Figure 4.1-6). Within less than 100 ft (30.5 m), the ΔT from the western pump was 28 F (18.6 C) or less. High ΔT water hugged the outer breakwater, apparently as a possible consequence of the southwesterly winds which were blowing at the time (refer ahead to Figure 4.1-15). Surface ΔT's of 10 F (5.6 C) and greater were confined to the western third of the area between the breakwaters. The remainder of the area experienced ΔT's equal to or colder than observed prior to backwashing (Figure 4.1-2). At the 3.3 ft (1.0 m) depth ΔT's were 23.4 to 24.3F(13.0 to 13.5 C) in front of the intake. Within less than 200 ft (61 m) they were down to 18.2 F (10.1 C); beyond that distance they were 14.8 to 6.7 F (8.2 to 3.7 C). Near the outer end of the breakwaters ΔT's were 2.4 to 3.3 F (1.3 to 1.8 C).

At 9.8 ft (3.0 m), ΔT's were 4.6 F (2.6 C) or less in front of the intake and 1.2 to 2.1 F (0.7 to 1.2 C) along the dredged channel (Figure 4.1-7). Along the bottom all of the ΔT's were negative, or colder than conditions at the outer end of the breakwaters. Maximum values were -4.4 F (-2.4 C) at Station 6.

The continuous profiles at Station 6 showed that the backwashing from the western pump formed a distinct slug or pulse of hot water along the surface and extended down to about 7 ft (2.1 m). The heated effluent apparently took about 15 min to reach and about 75 min to pass the anchored boat (Figure 4.1-4), as it progressed seaward. Maximum observed ΔT at the surface was 22.6 F (12.5 C) which represented an actual temperature of 79.0 F (26.1 C). Near-bottom temperatures were 53.4 to 56.2 F (11.9 to 13.4 C) which represented negative ΔT's of up to -4.7 F (-2.6 C).

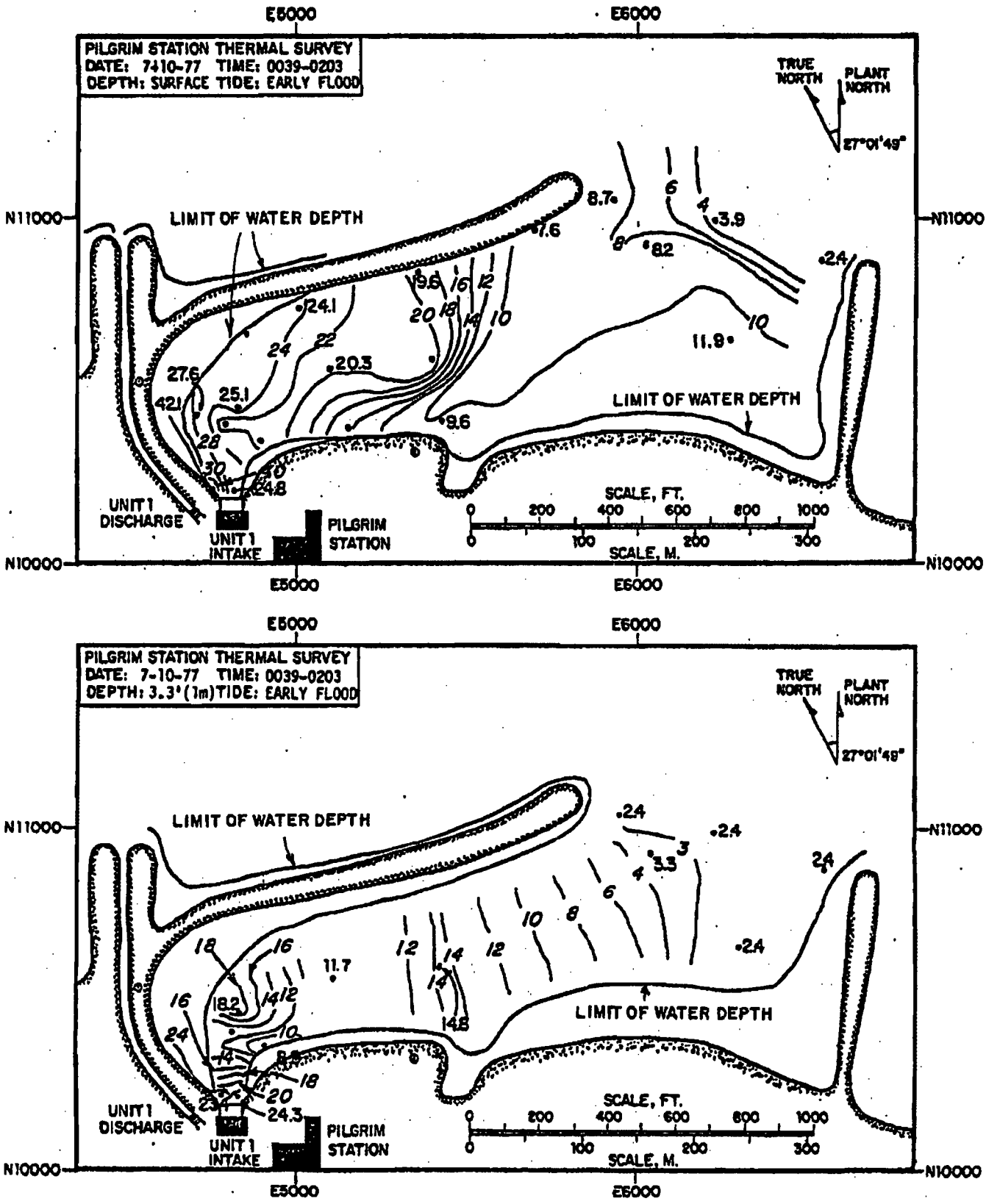

Figure 4.1-6. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during early flood (backwash west pump) at surface and 3.3 ft (1.0 m) on July 10, 1977. Pilgrim Station Backwashing Studies, 1977.

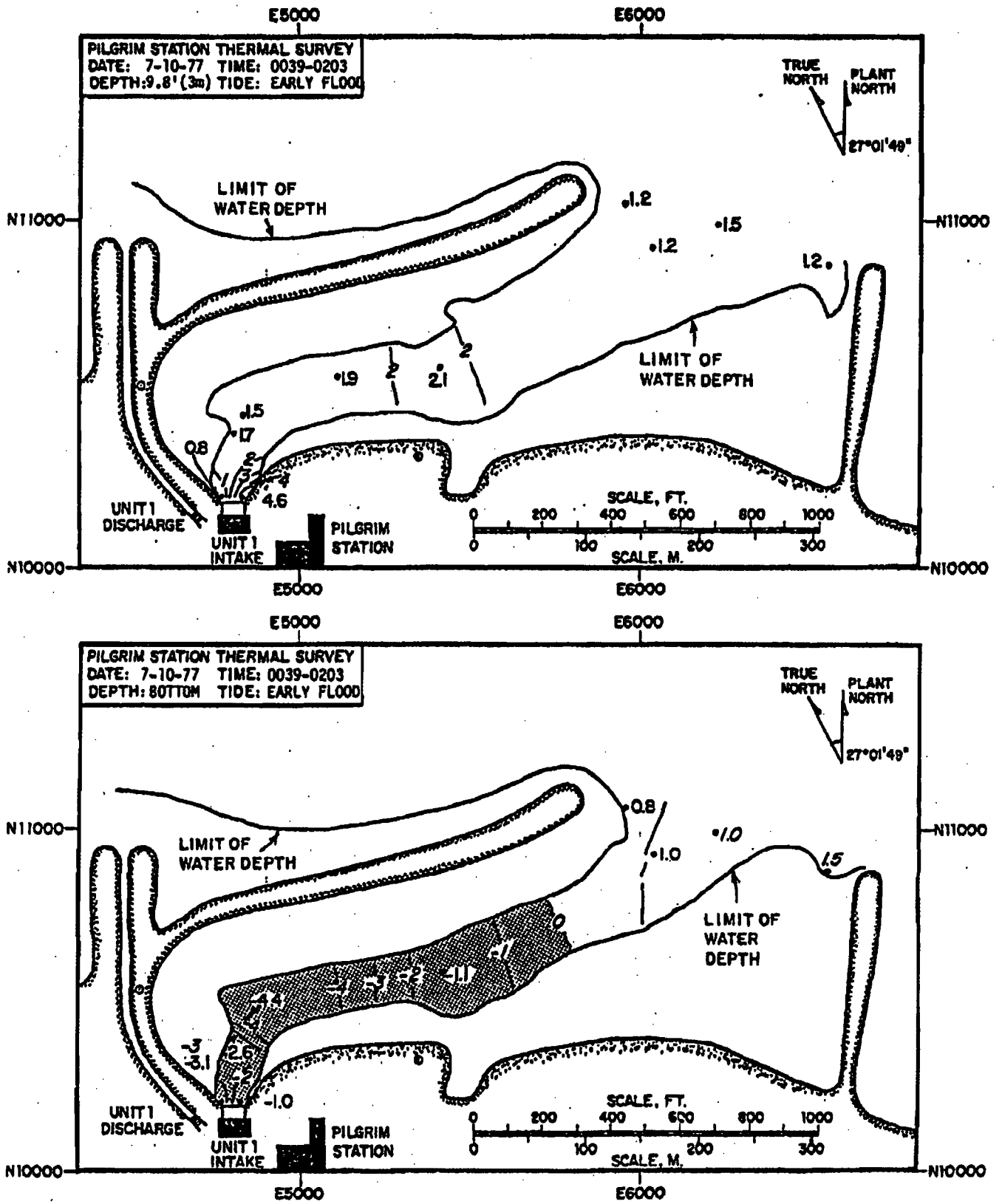

Figure 4.1-7. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during early flood (backwash west pump) at 9.8 ft (3.0 m) and bottom on July 10, 1977. Pilgrim Station Backwashing

Further away at Station 15 a similar slug of backwash water was observed (Figure 4.1-5). It was slightly colder than what was observed at Station 6 (maximum temperature 77.0 F or 25.0 C representing a 19.8 F or 11.0 C ΔT). In addition this plume was thinner (only about 3.3 ft or 1.0 m). It took about 30 min from the start of backwashing to reach the anchored boat and about 45 min to pass. Near-bottom temperatures remained cold (49.8 to 55.0 F or 9.9 to 12.8 C), showing negative ΔT's as low as -7.4 F or -4.1 C.

By about 0119 EST backwashing of the west pump was complete.

4.1.3.3 Mid Flood (Backwash East Pump)-0204 to 0309 EST

At about 0150 EST backwashing of the east circulating water pump started. As before, there was a sudden surge of hot, turbulent and steam water at the surface; within minutes a thin thermal plume and a distinct frontal zone was observed to be moving seaward.

At the surface, ΔT's of 43.4 F (24.1 C) and 23.9 F (13.3 C) occurred in front of the east and west pumps respectively (Figure 4.1-8). This was essentially the same as during backwashing of the west pump (Figure 4.1-6). Surface ΔT's were generally 20 F (11.1 C) and more across the western third of the study area; the middle third was 10 to 20 F (5.6 to 11.1 C); and the eastern third 5 to 10 F (2.8 to 5.6 C). As before, the highest temperatures were along the outer breakwater. At 3.3 ft (1.0 m) ΔT's were 15.5 to 23.4 F (8.6 to 13.0 C) next to the intake and gradually decreased seaward to 1.9 F or 1.0 C at Station 27.

At 9.8 ft (3.0 m) there was no evidence of the backwash plume (Figure 4.1-9). Observed ΔT's ranged from 1.2 to 3.3 F (0.7 to 1.8 C). Along the bottom ΔT's remained negative and actually increased in the negative sense from earlier in the evening (down to -4.9 F or -2.7 C).

At Station 6 the second backwash manifested itself as another pulse of hot water, warmer than before (up to 81.1 F or 27.3 C), but slightly thinner and not lasting as long (Figure 4.1-4). This plume was represented by ΔT's of up to 23.5 F (13.1 C) at the surface. Apparently

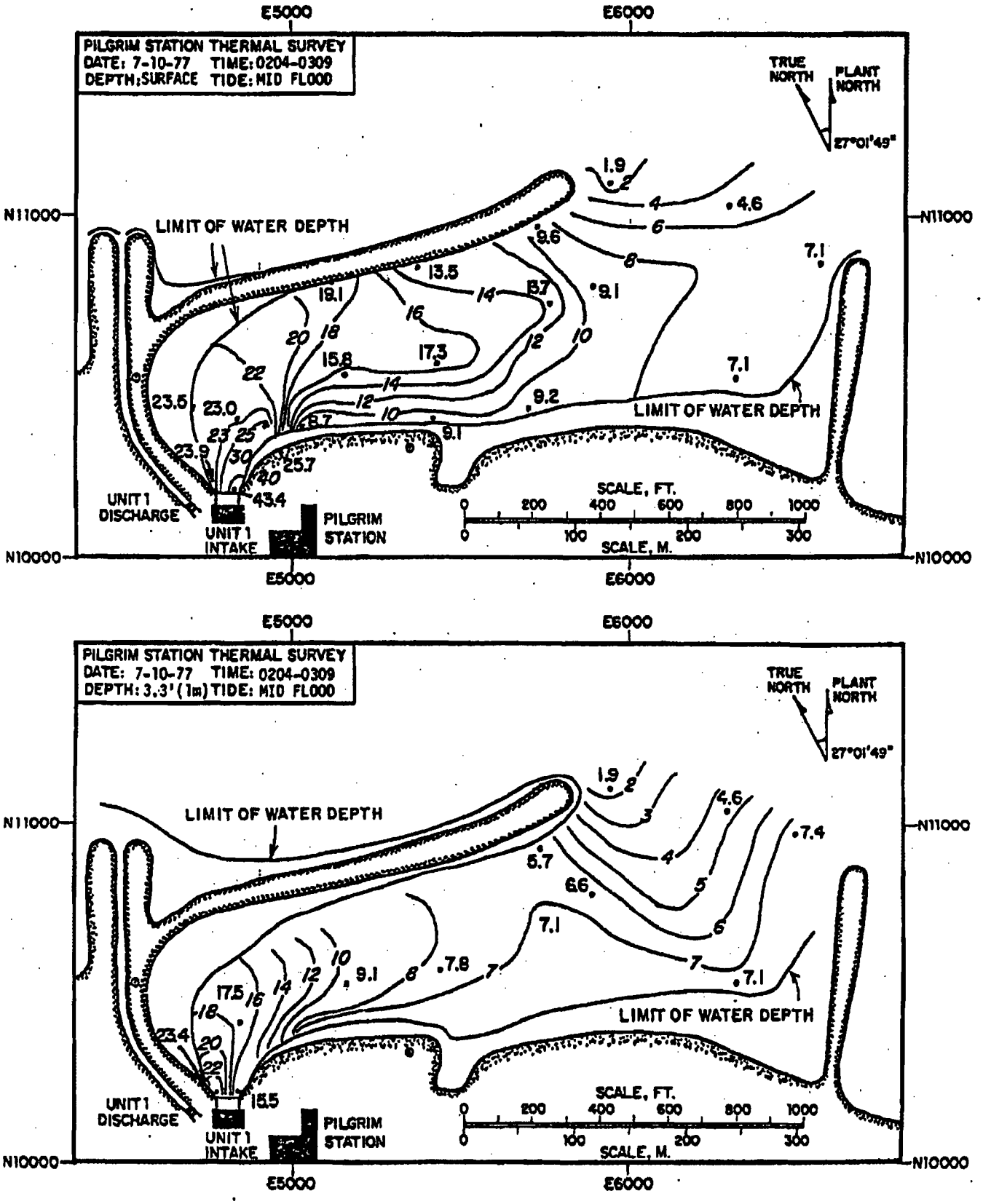

Figure 4.1-8. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during mid flood (backwash east pump) at surface and 3.3 ft (1.0 m) on July 10, 1977. Pilgrm Station Backwashing Studies, 1977

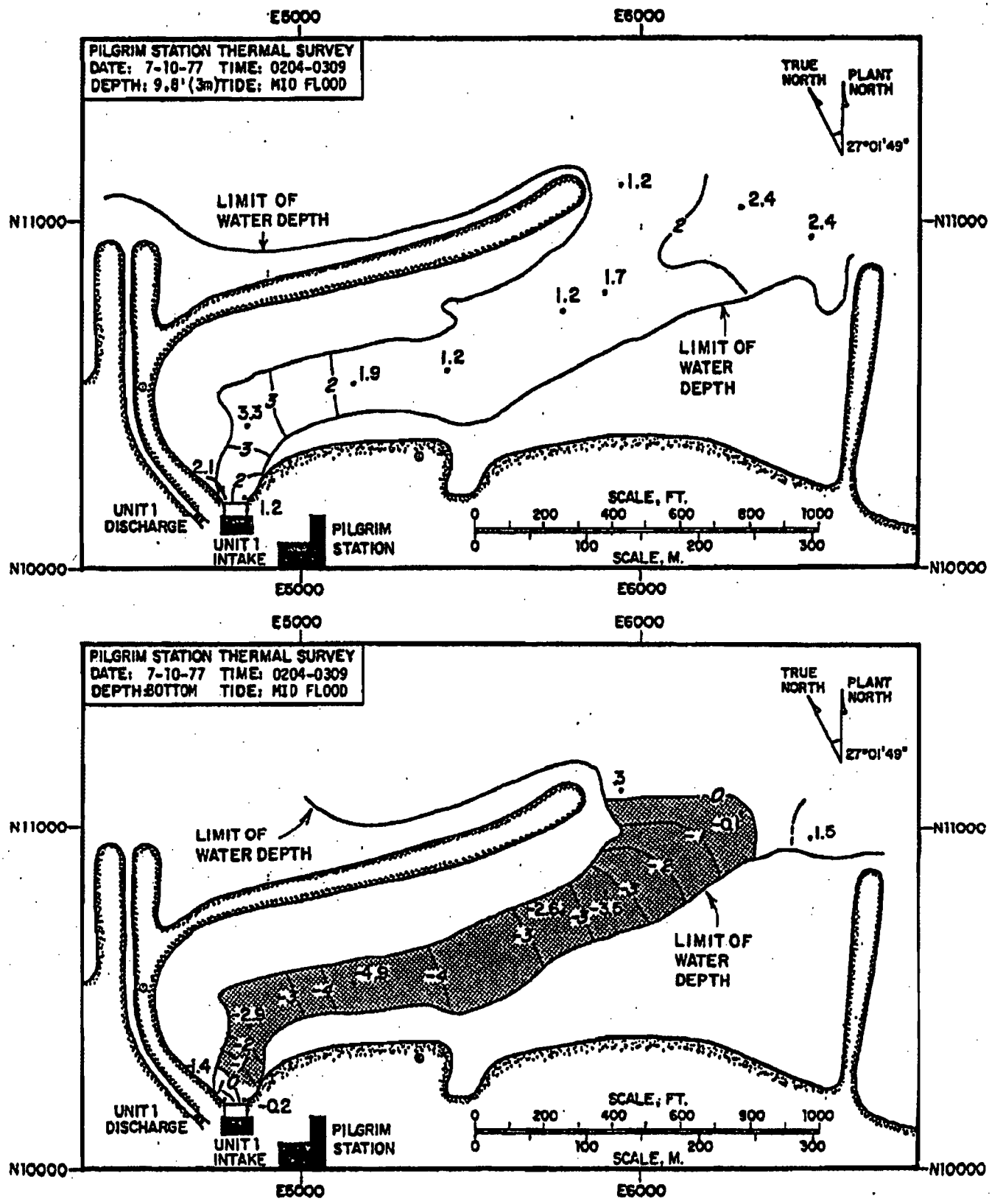

Figure 4.1-9. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during mid flood (backwash east pump) at 9.8 ft (3.0 m) and bottom on July 10, 1077. Pilgrim Station Backwashing Studies, 1977.

it took about 10 to 15 min for this second plume to reach the anchored boat, but its effects were only seen for about 60 min. By the time the plume had passed, it was only about 1 to 2 ft (0.3 to 0.6 m) thick. Near-bottom temperatures showed little change, ranging from 54.1 to 56.2 F (12.3 to 13.4 C) and representing negative ΔT's (down to -3.4 F or -1.9 C).

At Station 15 a second pulse of hot water from backwashing the east pump was observed. As before, it took about 30 min for the thermal plume to reach this location. It was colder than the first pulse (maximum temperature of 75.8 F or 24.3 C), thinner (only about 2 to 3 ft or 0.6 to 0.9 m) and persisted for about 45 min. Near-bottom temperature distribution remained unchanged.

By about 0227 EST backwashing of the east pump was complete.

4.1.3.4 Late Flood (Post Backwash)-0310 to 0415 EST

By the time this survey began, all backwashing had been completed for the night. The intake was again drawing water in from Cape Cod Bay and the thermal effluent was being discharged via the canal. Surface temperatures dropped dramatically from those of the previous hour, reflecting the rapid dissipation of backwash heat (Figure 4.1-10). The highest ΔT's were 11.4 F (6.3 C) at Station 1 and 9.6 F (5.3 C) at Station 2, both adjacent to the intake. At Stations 3,4, 6 and 7, in the western portion of the study area, ΔT's were actually negative (-1.0 F or-0.6 C). Elsewhere, ΔT's ranged from 1.5 to 5.3 F (0.8 to 2.9 C) with no residual pockets of hot water. Slightly deeper at 3.3 ft (1.0 m), the general temperature distribution was essentially the same as at the surface. It should be noted that by this time, strong winds from the northwest made offshore waters very rough (refer ahead to Figure 4.1-15).

At the 9.8 ft (3.0 m) level ΔT's were negative throughout the western half of the study area (up to -1.5 F or-0.8 C at Station 4) and 0 to 1.3 F (0 to 0.7 C) out to and beyond the breakwaters (Figure 4.1-

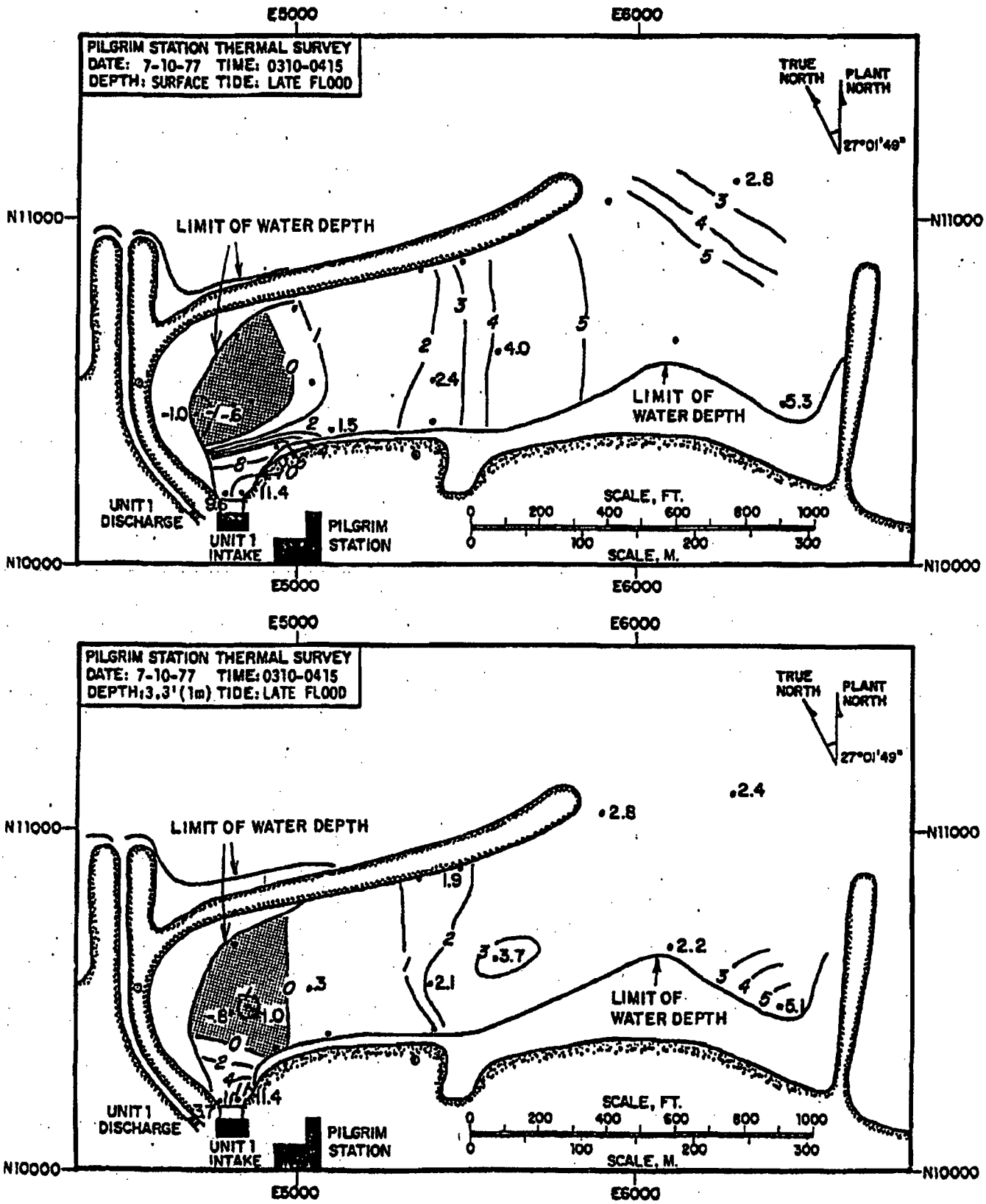

Figure 4.1-10. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during late flood (post-backwash) at surface and 3.3 ft (1.0 m) on July 10, 1977. Pilgrim Station Backwashing Studies, 1977.

11). Along the bottom ΔT's were even lower, ranging from -2.2 to -4.4 F (-1.2 to -2.4C) and essentially 0 at the outer end of the channel. These temperatures were quite similar to bottom conditions earlier in the night from 0204 to 0309 EST (Figure 4.1-9).

Once backwashing had been completed,water at Station 6 cooled off quickly (Figure 4.1-4). Surface temperatures dropped about 10 F (5.6 C) to 60.9 F (16.1 C) in less than an hour; whereas, bottom temperatures held between 55.0 and 57.0 F (12.8 and 13.9 C), representing ΔT's of down to -4.6 F (-2.6 C).

At Station 15, the water temperature also dropped quickly, reaching ambient levels or colder around 0330 EST (Figure 4.1-5). Thereafter, both surface and bottom temperatures gradually rose a few degrees, 63.3 F (17.4 C) and 56.2 F (13.4 C) respectively.

4.1.3.5 Late Flood (Survey Complete)-0416 to 0430 EST

By this time normal plant operations had resumed and all traces of hot water from backwashing were gone. At the surface, ΔT's were 1.0 to 2.6 F (0.6 to 1.4 C) in front of the intake and 0.6 and 3.1 F (0.3 to 1.7 C) further out at Stations 6 and 15 respectively (Figure 4.1-12). At 3.3 ft (1.0 m) ΔT's were 0.6 to 1.7 F (0.3 to 0.9 C). Deeper down at 9.8 ft (3.0 m) ΔT's were all negative, ranging from -0.6 to -1.5 F or -0.3 to -0.8 C (Figure 4.1-13). Finally along the bottom even greater negative ΔT's of -4.0 F (2.2 C) were observed.

4.1.3.6 Summary

The elevated surface temperatures from the backwashing operation persisted for about 2 to 2.5 hrs in the western portion of the study area and even less in the eastern portion, before being completely dissipated.

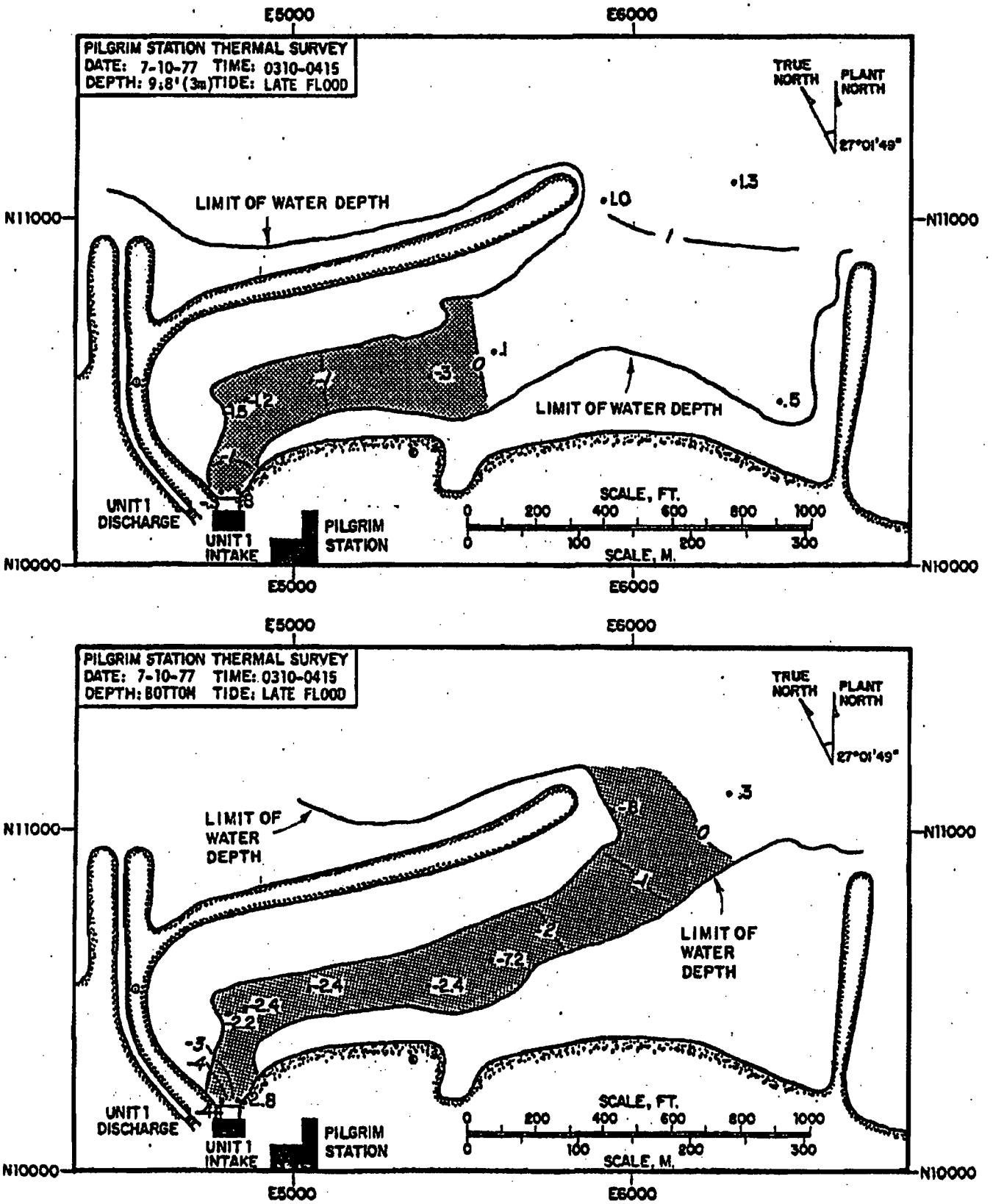

Figure 4.1-11 Contour maps of observed temperature rises (ΔT) in degrees F above ambient during late flood (postbackwash) at 9.8 ft (3.0 m) and bottom on July 10, 1977. Pilgrim Station Backwashing Studies, 1977.

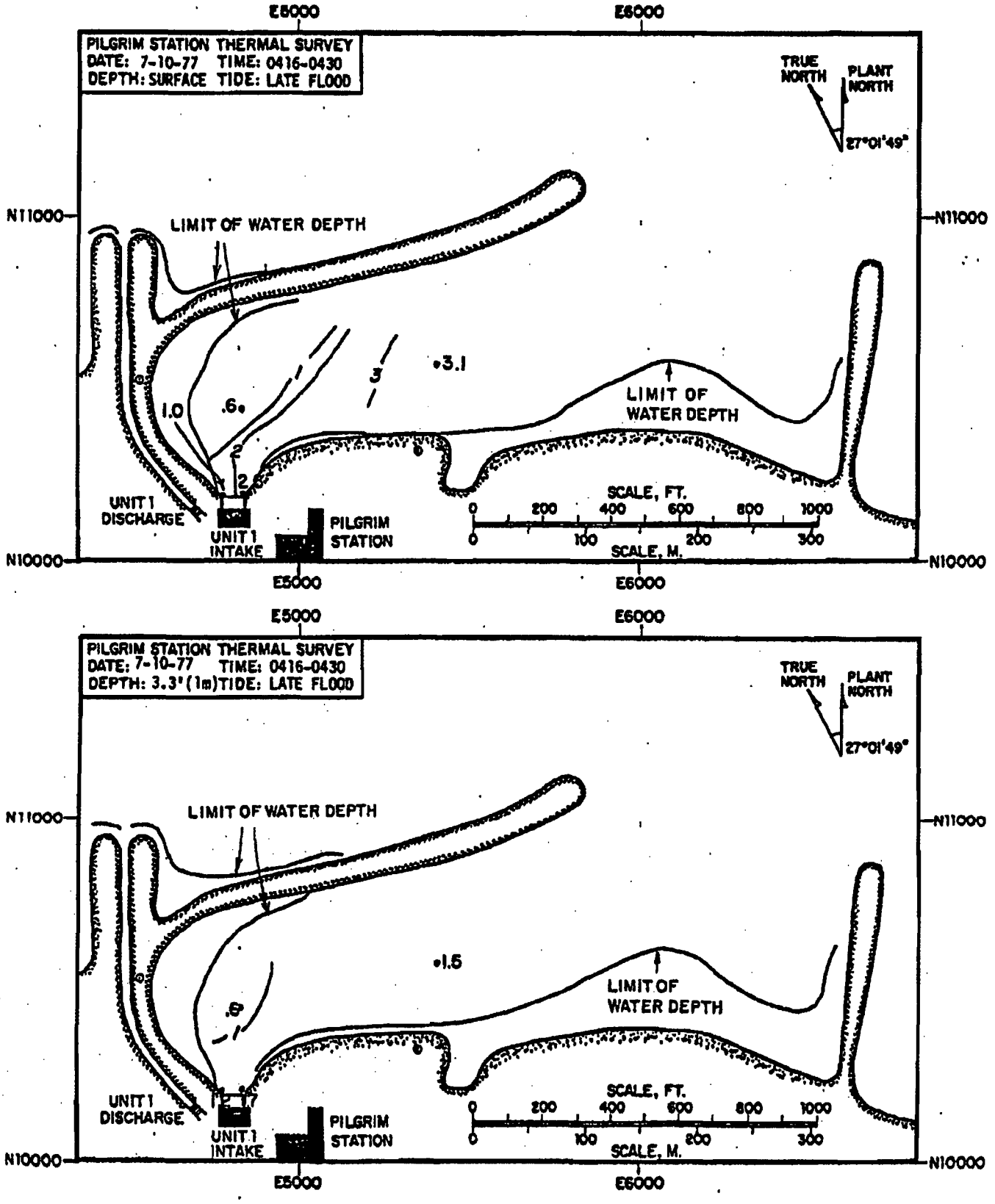

Figure 4.1-12. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during late flood (survey complete) at surface and 3.3 ft (1.0 m) on July 10, 1977. Pilgrim Station Backwashing Studies, 1977.

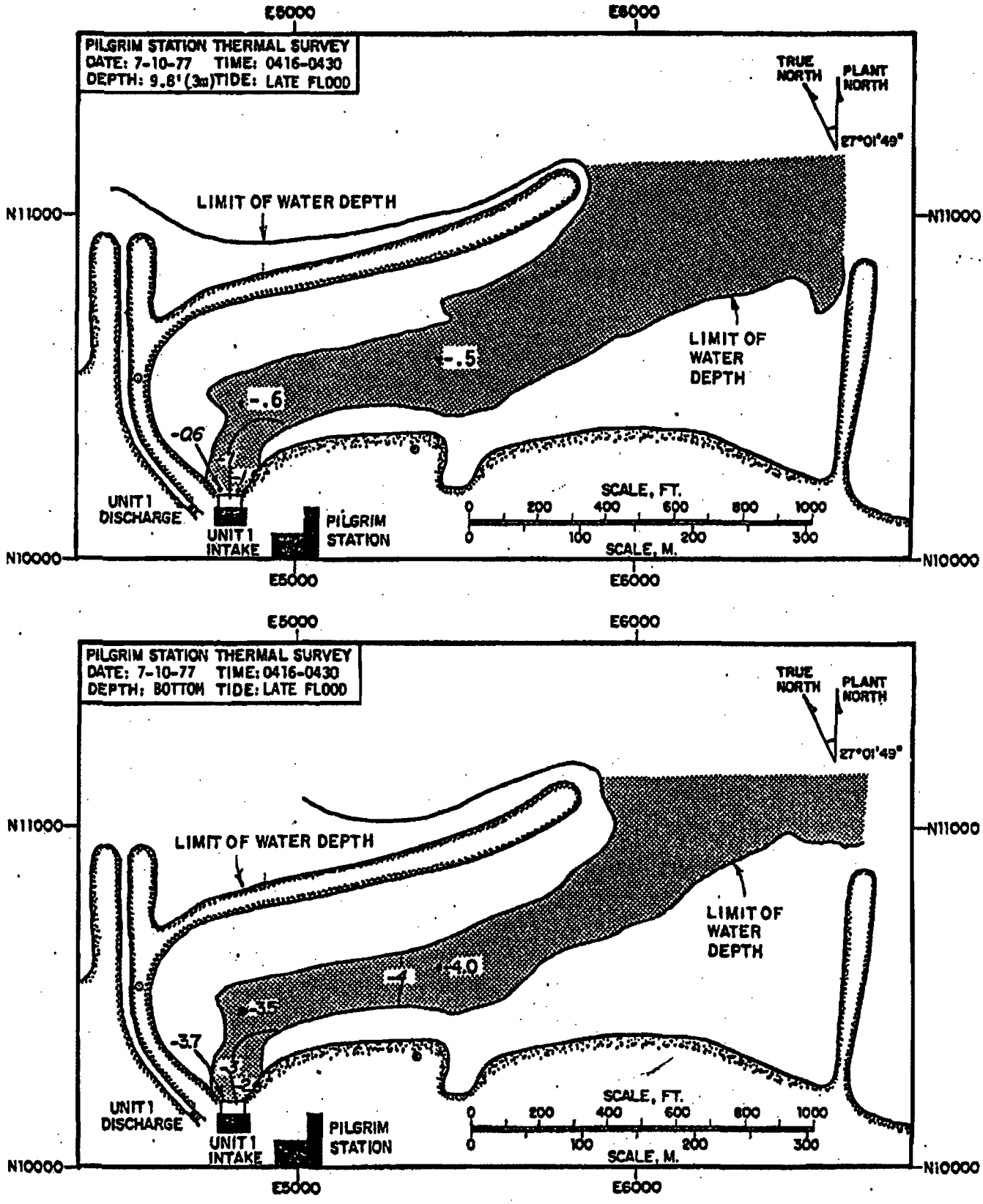

Figure 4.1-13. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during late flood (survey complete) at 9.8 ft (3.0 m) and bottom on July 10, 1977. Pilgrim Station Backwashing Studies, 1977.

4.1.4 CURRENTS

Flow patterns in the study area during the course of the July 9 and 10, 1977 survey were dominated by plant operation (Figure 4.1-14). In this figure, current vectors have been plotted relative to the instantaneous water surface, showing the direction toward which currents were flowing. At Station 1 adjacent to the intake and at Station 6 about 200 ft away, flows were southwestward or into the plant at 0.1 to 0.25 kn during the study period, except for during actual backwashing. Backwashing caused a shearing in the water column, with near-bottom currents continuing to flow toward the intake and near-surface currents of up to 0.3 kn flowing seaward. Once the backwash plume was established, continued pumping carried it away from the plant.

Current-meter data from other locations further seaward along the dredged channel showed near-surface flows in toward the plant throughout the night except during actual backwashing. The backwashing operation formed a seaward flowing near-surface layer which gradually spread away from the plant, entraining ambient waters and leasing out progressively thinner, the further it was carried. Near-bottom flows remained in toward the plant throughout the night.

4.1.5 AIR TEMPERATURE

Air temperature measurements at the 33-ft (10-m) level on Boston Edison Company's 160 ft (48.8 m) meteorological tower (Figure 2.1-1) showed a gradual late afternoon warming trend to a peak of 73 F (22.7 C) around 1800 EST (Figure 4.1-15). Then temperatures cooled slightly to 70 F (21.1 C) before a rapid drop from midnight to 0400 EST with a leveling off to about 63 F (17.2 C).

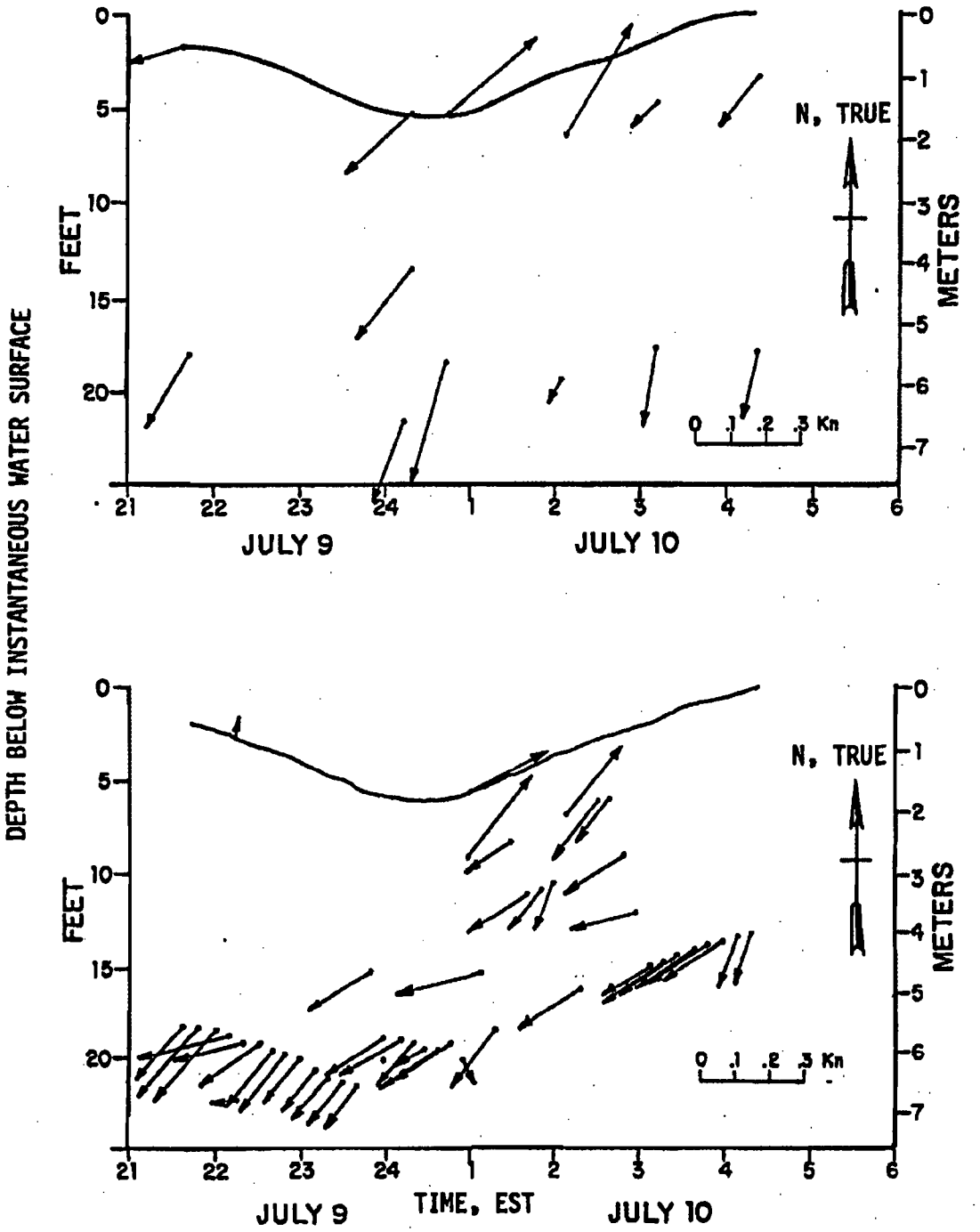

Figure 4.1-14. Vector plots of current measurements in degrees true (referenced toward where currents were flowing and kn from Station 1 (upper) and Station 6 (lower) on July 9 and 10, 1977. Pilgrim Station Backwashing Studies, 1977.

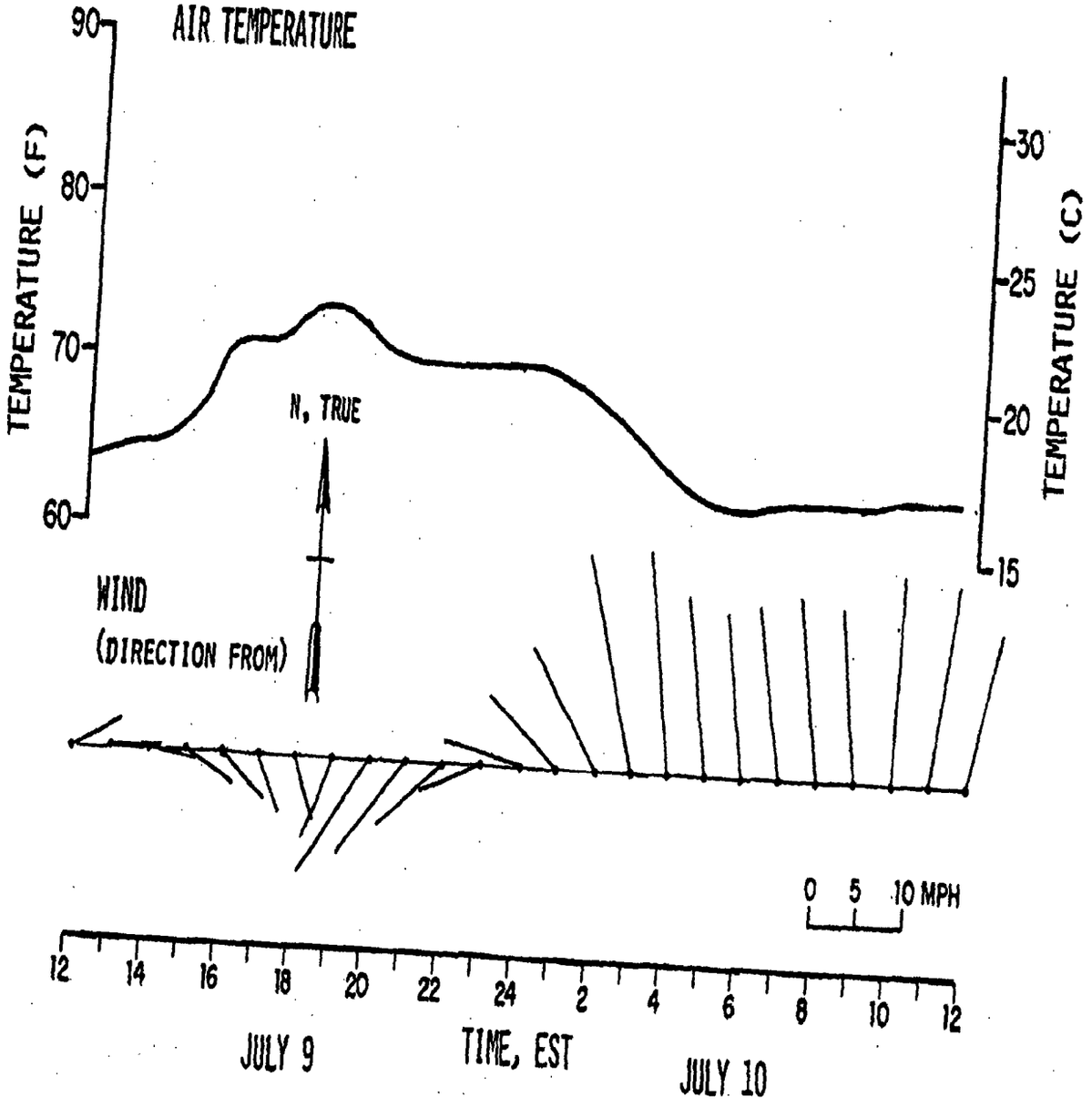

Figure 4.1-15. Air temperature and wind vector plots in degrees true (referenced from which wind was blowing) and mph from the 33 ft (10 m) level of the Boston Edison Company meteorological tower on July 9 and 10, 1977. Pilgrim Station Backwashing Studies, 1977.

4.1.6 WIND CONDITIONS

Wind speed and direction measurements at the 33-ft (10-m) level on Boston Edison Company's 160 ft (48.8 m) meteorological tower showed a pronounced change during the night (Figure 4.1-15). During the late afternoon and evening of July 9, 1977, winds were from the southwest at 8 to 10 miles per hour (mph). From midnight to 0200 EST they swung around to northwest, then started blowing stronger at 11 to 14 mph. As the night progressed, the winds became more northerly and seas outside the breakwater became very choppy. Wind stress may have helped force the backwash plume along the outer breakwater during the early flood survey (Figure 4.1-6); but during the rest of the survey, the outer breakwater apparently provided sufficient shelter to negate any effects of the onshore winds.

4.1.7 TIDES

The tide observations showed good agreement with NOAA-NOS tide predictions (Figure 4.1-16).

4.2 JULY 16 AND 17 HIGH-WATER BACKWASH SURVEY

4.2.1 PLANT OPERATION

One week after the first survey, a second survey under different tidal conditions was conducted. As before, this backwash survey consisted of five sampling runs keyed to actual plant operation (Table 4.2.1 and Figure 4.2-1). Plant load was gradually brought down, resulting in a lowering of temperatures in the discharge canal from about 84 F (28.9 C) to about 74 F (23.3 C). The western pump (B) was backwashed from about 2350 to 0113 EST. The *in-situ* temperature monitor in the discharge canal showed a gradual lowering of discharge temperature to about 73 F (22.8 C), then a sudden short peak at the end of backwashing to 80 F (26.7 C; Figure 4.2-1). Simultaneously, the waterbox temperature rose sharply to about 97 F (36.1 C). Toward the end of the 73-min backwash

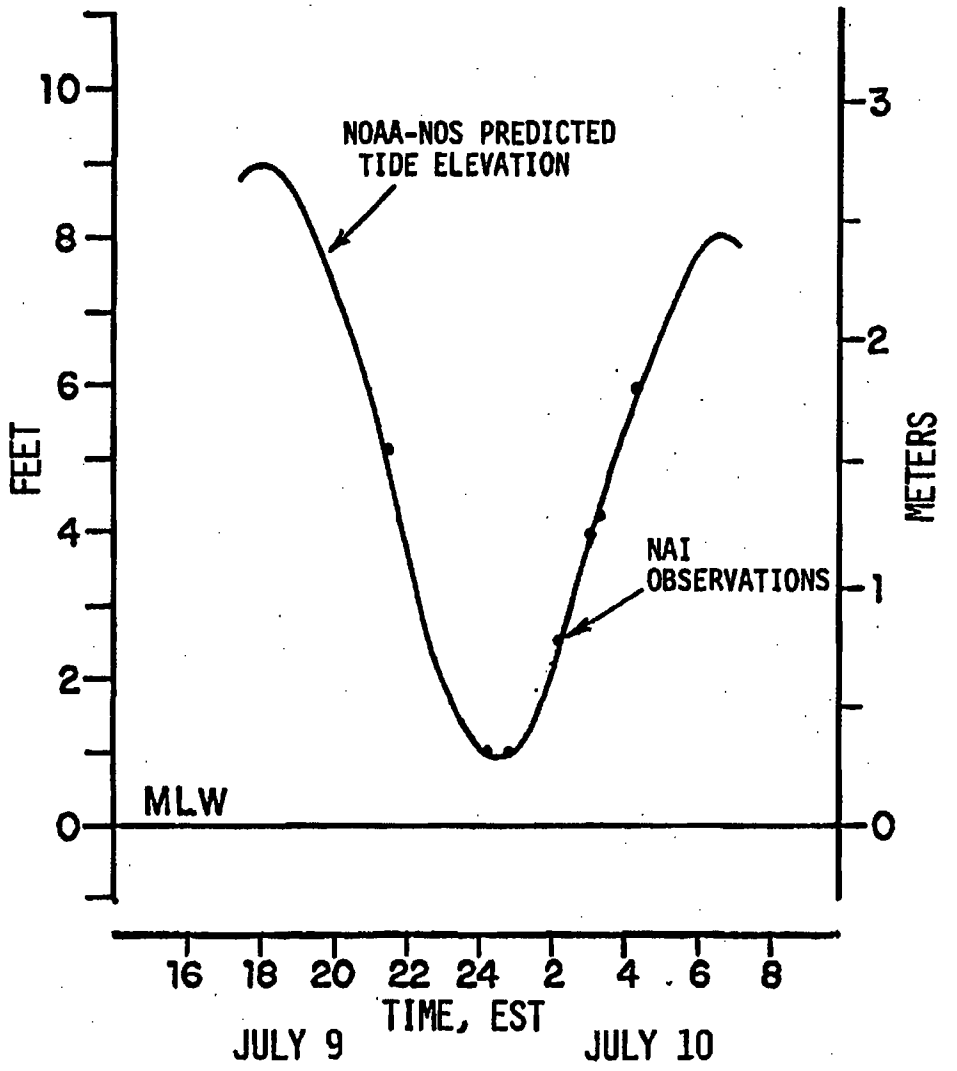

Figure 4.1-16. Plot of NOAA-NOS predicted tide elevations for the Pilgrim Station area along with NAI tide observations for July 9 and 10, 1977. Pilgrim Station Backwashing Studies, 1977.

TABLE 4.2-1. SAMPLING RUNS AND AMBIENT BASE TEMPERATURES FROM STATION 28 FOR THE JULY 16 AND 17, 1977 HIGH-WATER BACKWASH SURVEY.

SAMPLING RUN	TIDE STAGE	(PLANT STATUS)	SAMPLING INTERVAL; EST	AMBIENT BASE TEMPERATURE		AMBIENT TEMPERATURE RANGE MAXIMUM		MINIMUM	
				F	C	F	C	F	C
1	Late flood	(Pre backwash)	2302 to 0002	53.6	12.0				
2	Early ebb	(Backwash West Pump)	0003 to 0139	54.7	12.6				
3	Mid ebb	(Backwash East Pump)	0140 to 0349	51.6	10.9	No Data Available			
4	Late ebb	(Post backwash)	0350 to 0517	52.5	11.4				
5	Low water	(Survey complete)	0518 to 0538	52.5	11.4				

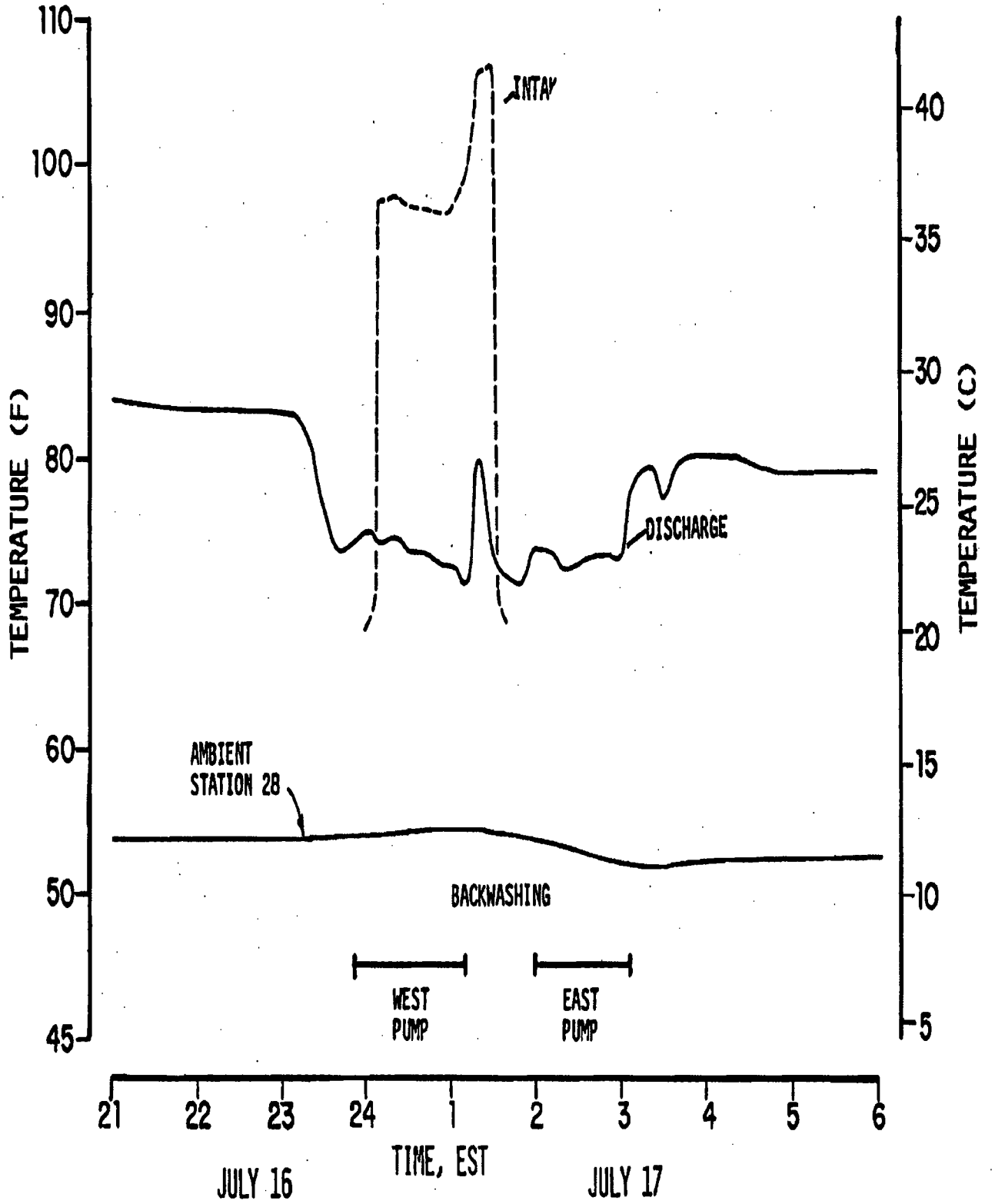

Figure 4.2-1. Temperature monitor data from the west pump waterbox, the discharge canal and the ambient Station 28 during backwashing operations on July 16 and 17, 1977. Pilgrim Station Backwashing Studies, 1977.

cycle, temperatures peaked at 107 F (41.7 C). The jump in discharge temperature is attributed to the short period of normal pumping before backwashing began on the east pump (A) at about 0159 EST. After about 68 min of backwashing on this pump, the plant resumed normal operations (around 0307 EST) and discharge temperatures increased to around 80 F (26.7 C). Backwash temperatures were about the same for both pumps; however, this series of backwashes lasted 20 to 25 min longer than respective ones the week before. The time extension of the backwash period is attributed to increased fouling of the condenser tubes,

4.2.2 AMBIENT TEMPERATURES

The rationale for determining ambient temperature was the same as for the July 9 and 10 survey (see Section 4.1.2). Temperature data from the near-bottom ambient reference location (Station 28) showed relatively little change overnight (Figure 4.2-1). The *in-situ* monitor worked for only a short period of time before becoming inoperative; therefore, the profile data from the survey boat had to be used to determine the ambient base temperature for each sampling run (Table 4.2-1).

4.2.3 THERMAL SURVEYS

4.2.3.1 Late Flood (Prebackwash)-2302 to 0002 EST

The prebackwash survey during late flood tide was conducted from 2302 EST on July 16 through 0002 EST on July 17. Surface ΔT's showed temperature rises of 3.7 to 6.4 F (2.1 to 3.6 C) inside the breakwaters (based on ambient of 53.6 F or 12.0 C and 21.6 F or 12.0 C near the end of the discharge canal (Figure 4.2-2). At the 3.3 ft (1.0 m) depth ΔT's were somewhat lower, ranging from 1.9 to 4.6 F (1.1 to 2.6 C) in the study area and 8.5 F (4.7 C) at the discharge. Data from 9.8 ft (3.0 m) showed ΔT's of 0.7 to 3.0 F (0.4 to 1.7 C); whereas, at the bottom the ΔT's showed temperatures very close to ambient (range from 1.2 to -0.2 F or 0.7 to -0.1 C; Figure 4.2-3).

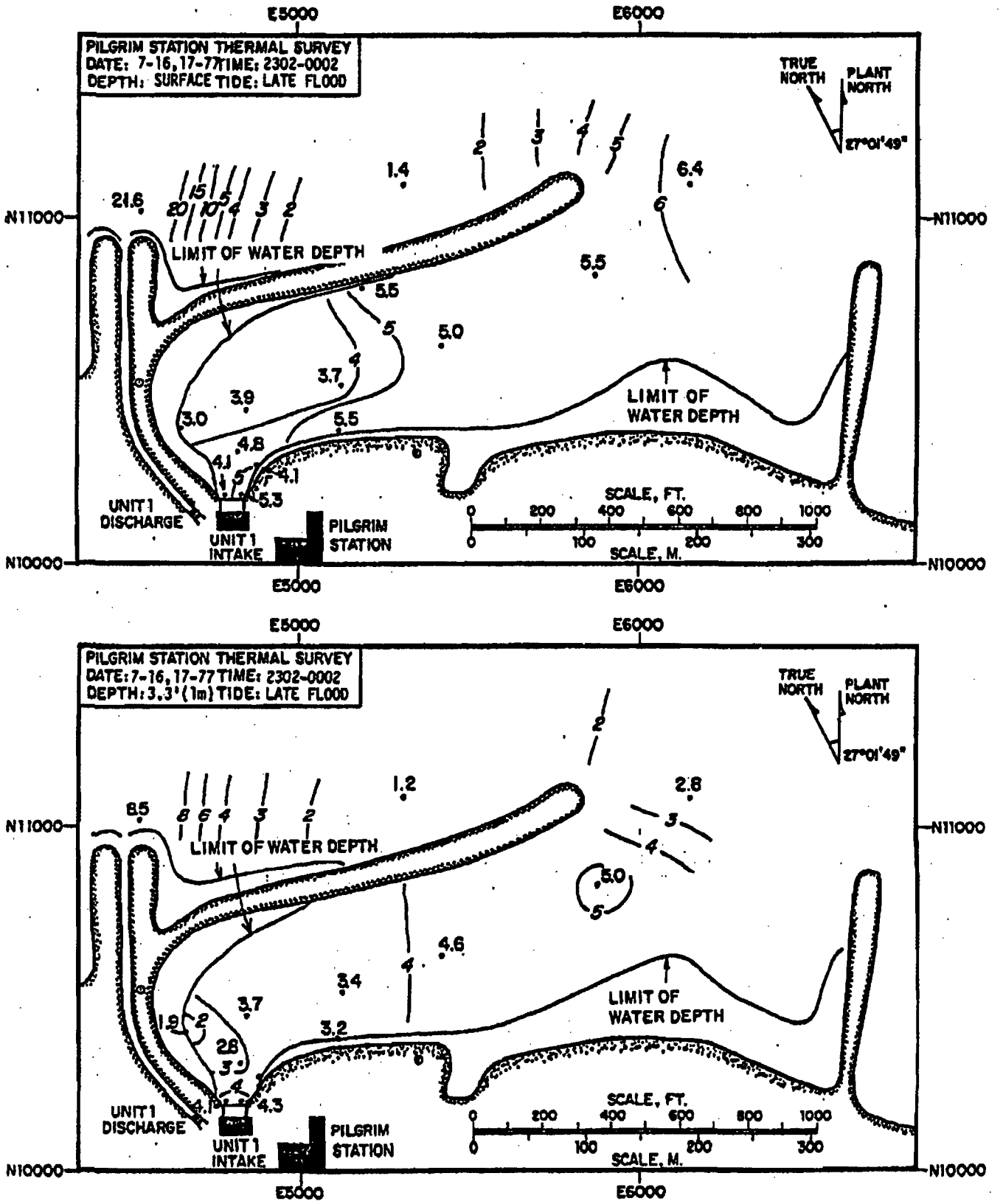

Figure 4.2-2. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during late flood (preback-wash) at surface and 3.3 ft (1.0 m) on July 16 and 17, 1977. Pilgrim Station Backwashing Studies, 1977.

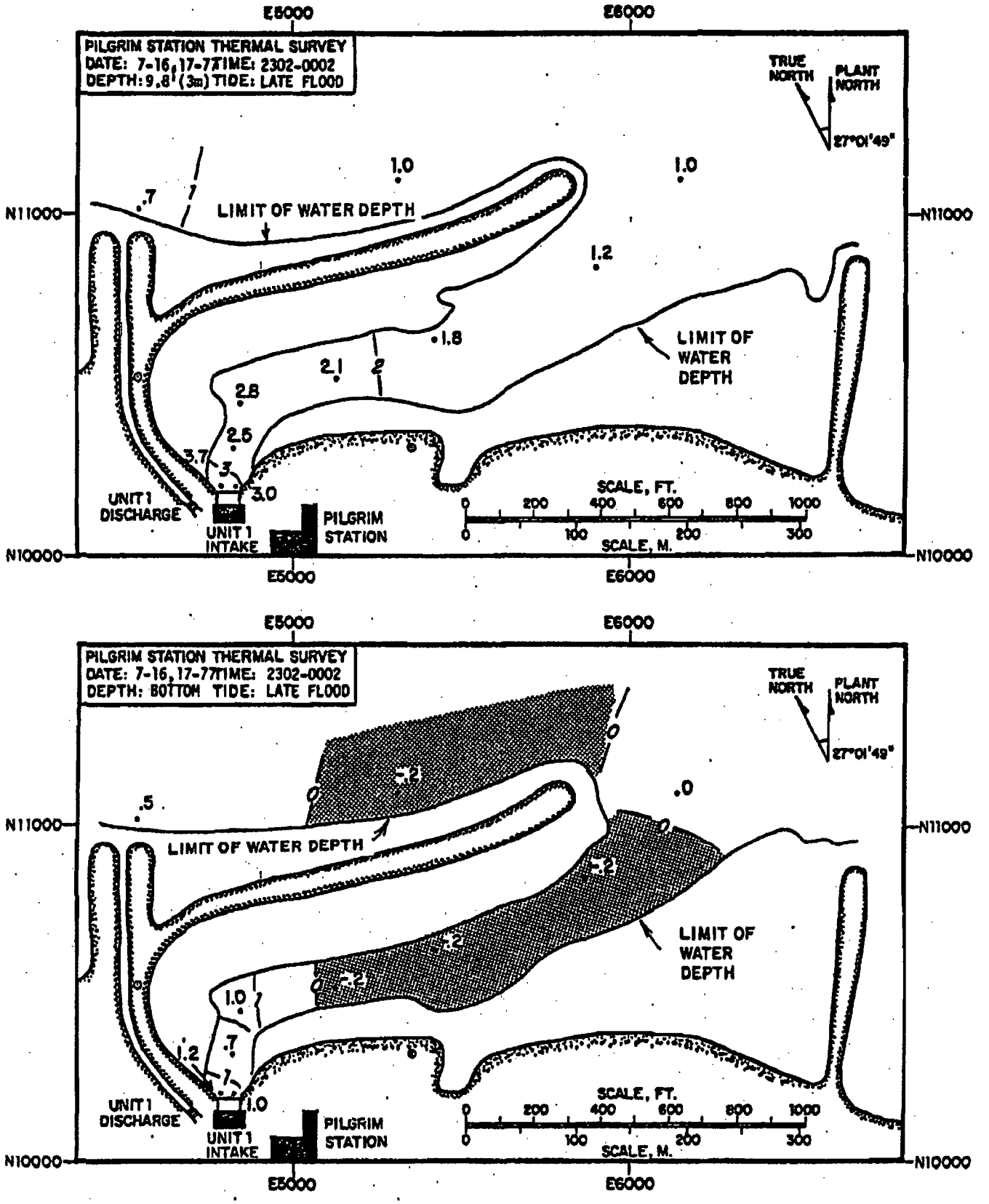

Figure 4.2-3. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during late flood (preback-wash) at 9.8 ft (3.0 m) and bottom on July 16 and 17, 1977. Pilgrim Station Backwashing Studies, 1977.

Measurements from the anchored boat at Station 6 (Figure 4.2-4), were consistent with the survey vessel data showing surface ΔT's of 4.2 F (2.3 C) which corresponded to an actual temperature of 57.8 F (14.3 C). Bottom temperatures were as low as 52.9 F (11.6 C), representing a ΔT of -0.7 F (-0.4 C).

Further along the dredged channel at Station 15 (Figure 3.1-2), temperatures were slightly warmer (Figure 4.2-5). The surface temperature was 58.6 F (14.8 C) or ΔT of 5.5 F (3.1 C) above ambient.

4.2.3.2 Early Ebb (Backwash West Pump)-0003 to 0139 EST

At about 2354 EST backwashing started on the west pump. This time, in sharp contrast to the low-water backwashing, the surface appearance of the backwash waters was much less dramatic. The thermal plume was somewhat turbulent and steamy, but the thermal front along the interface with Cape Cod Bay waters was much less distinct that it had been the week before. That is, this backwashing thermal plume lacked a sharp interface which could be readily discerned with the naked eye, probably because more dilution or "receiving" water was available at high water than during the low-water backwash the week before.

The surface ΔT's were 28.2 F (15.7 C) in front of the west pump and 17.1 F (9.5 C) in front of the east pump (Figure 4.2-6). Warmest temperatures were along the west side of the study area with ΔT's from 28.0 F down to about 14.8 F (15.6 to 8.2 C).

Across the middle portion of the study area, ΔT's ranged from 15 to 10 F (18.3 to 15.6 C) with most of the hot water apparently being blown against the outer breakwater by the strong southwesterly winds which persisted throughout the survey (refer ahead to Figure 4.2-16). Much lower ΔT's were seen along the shore in front of the power plant (6.1 to 9.1 F or 3.4 to 5.1 C). In the eastern portion of the study area, some warm water was observed along the outer breakwater (8.7 to 11.8 F or 4.8 to 6.6 C); but, close to shore at Stations 23 and 24,

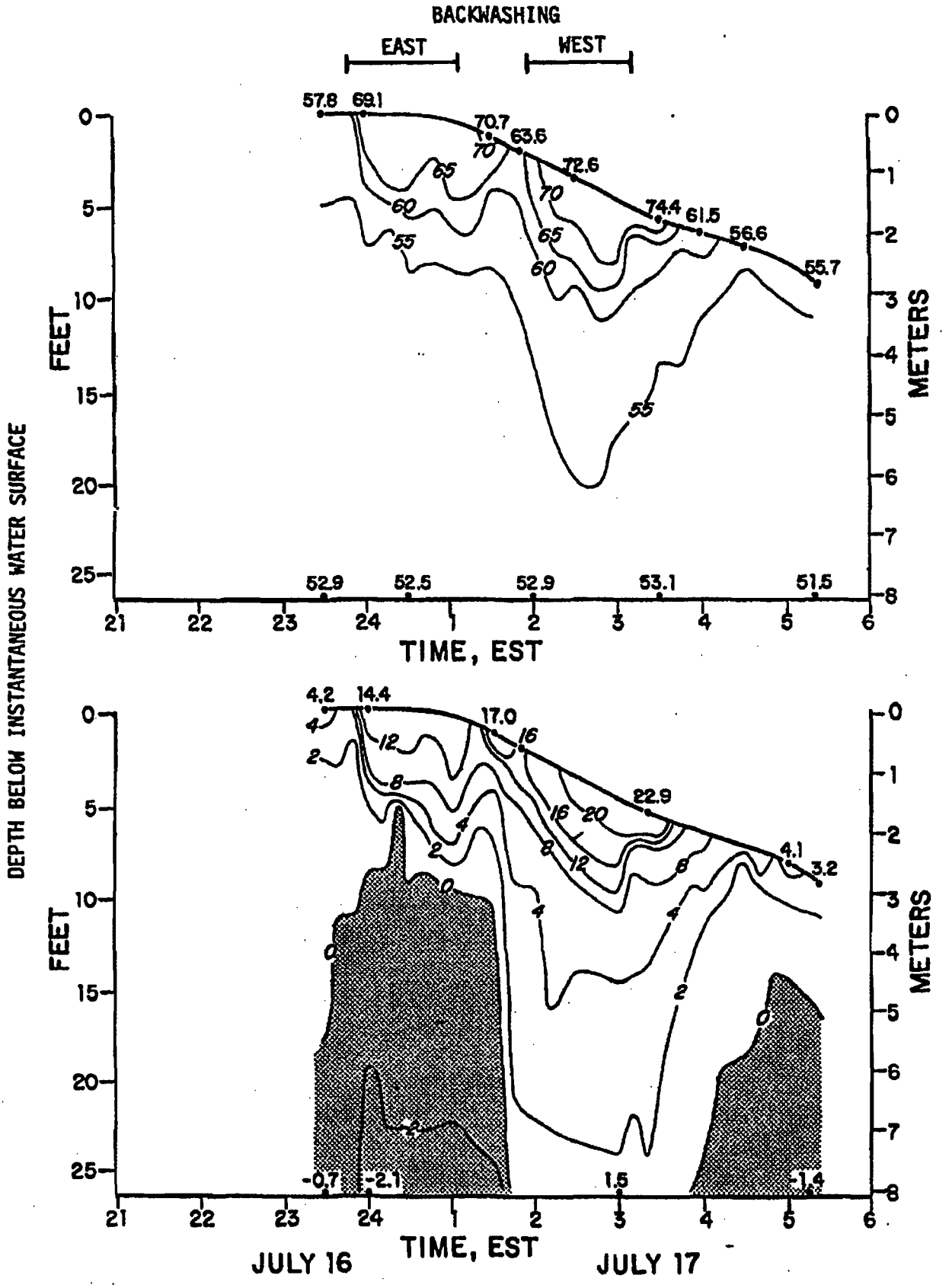

Figure 4.2-4. Temperature data from an anchored survey boat at Station 6 on July 16 and 17, 1977 showing actual temperatures and corresponding ΔT's above ambient in degrees F. Pilgrim Station Backwashing Studies, 1977.

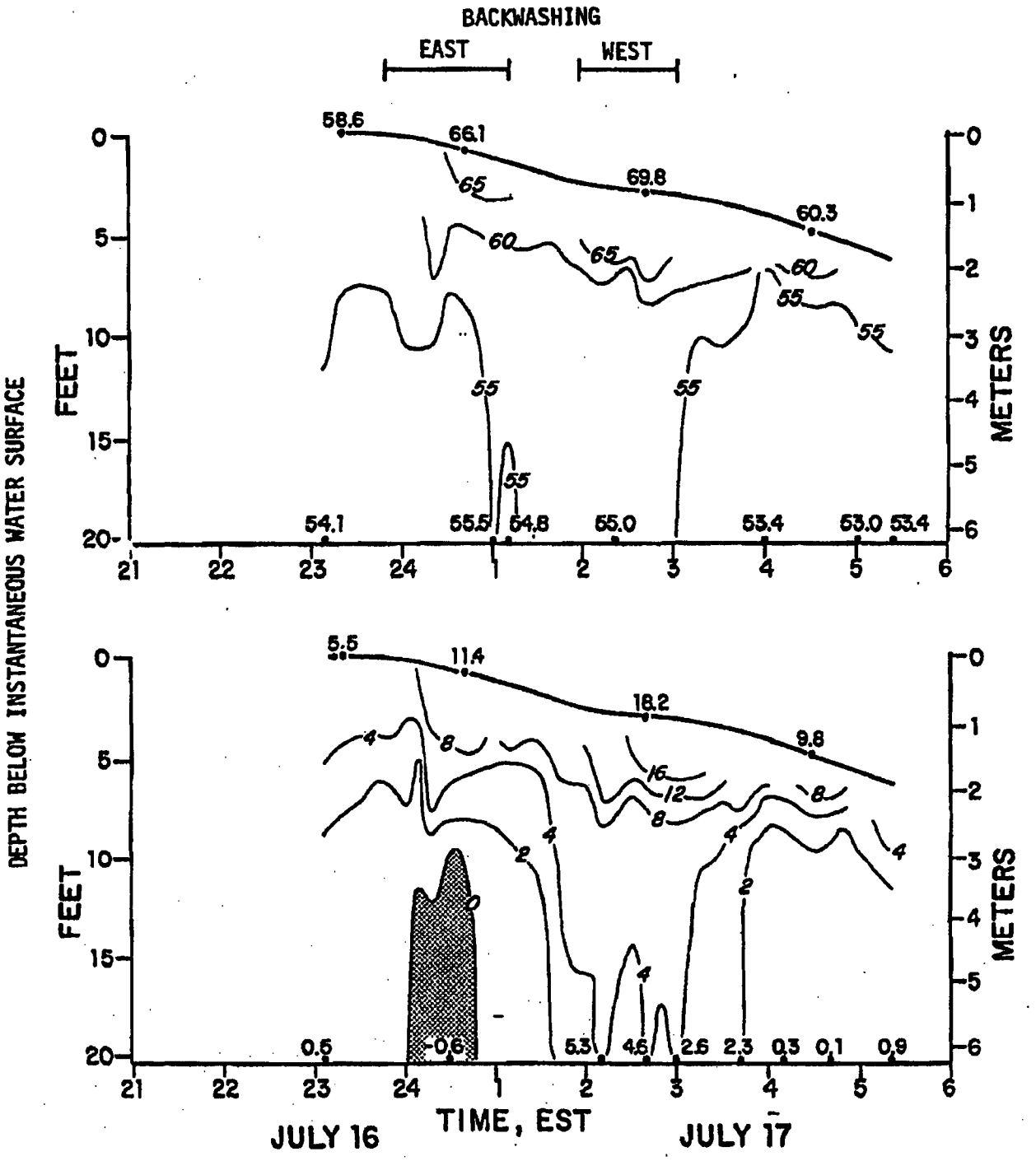

Figure 4.2-5. Temperature data from an anchored survey boat at Station 15 on July 16 and 17, 1977 showing actual temperatures and corresponding ΔT's above ambient in degrees F. Pilgrim Station Backwashing Studies, 1977.

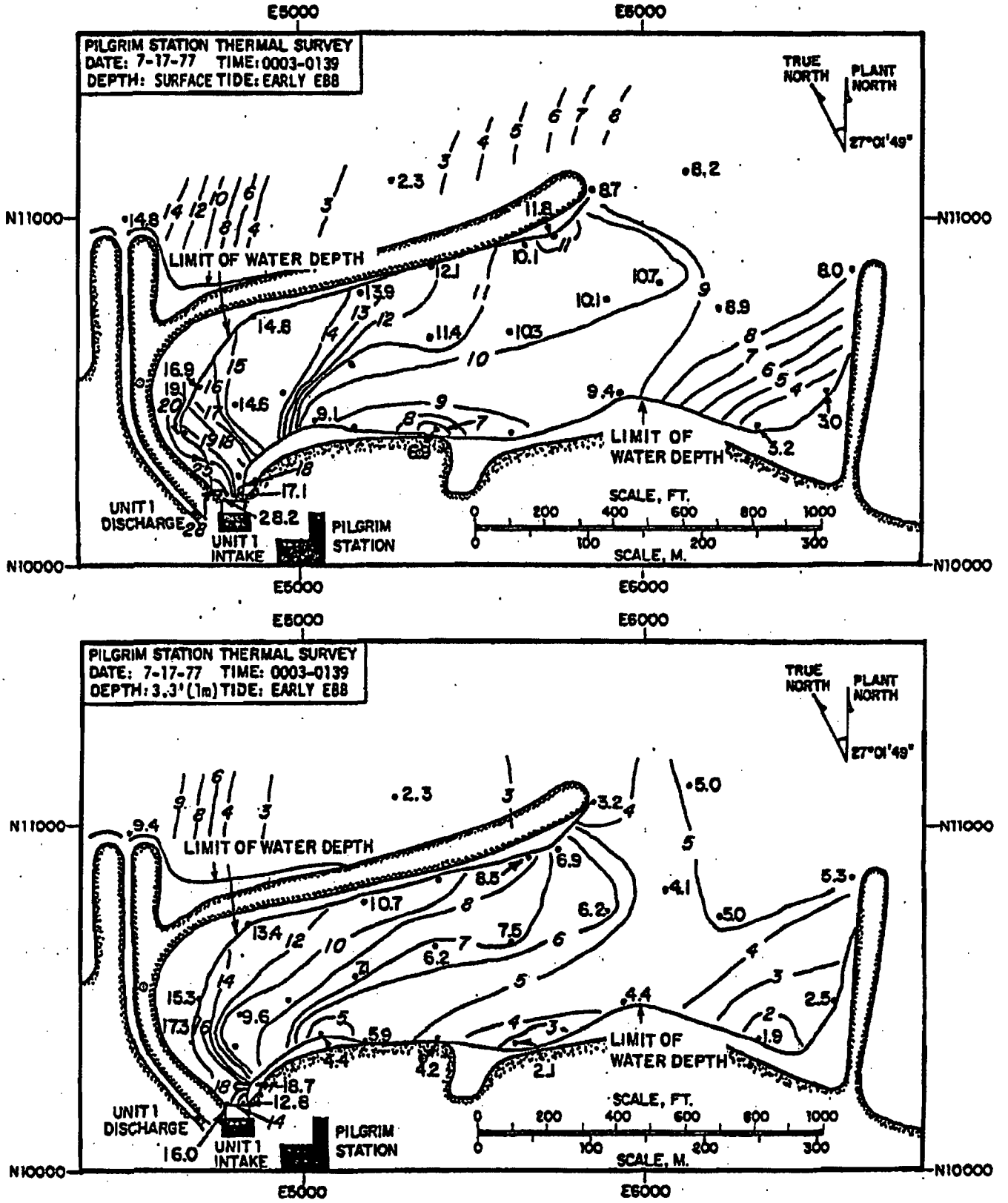

Figure 4.2-6. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during early ebb (backwash west pump) at surface and 3.3 ft (1.0 m) on July 17, 1977. Pilgrim Station Backwashing Studies, 1977.

prebackwash conditions were observed (ΔT's of 3.0 to 3.2 F or 1.7 to 1.8 C). At the discharge the temperature rise was 14.8 F (8.2 C). At the 3.3 ft (1.0 m) level ΔT's were lower than at the surface, but the general distribution of the backwash plume was about the same (Figure 4.2-6). These ranged from 13.8 and 16.0 F (7.7 and 8.9 C) in front of the intake, to 5.0 F (2.8 C) and less out at the end of the breakwaters. At the discharge the ΔT was 9.4 F (5.2 C).

At 9.8 ft (3.0 m) ΔT's were small, ranging from near 0 at the intake to 0.1 to 1.9 F (0.06 to 1.1 C) at the end of the discharge canal. All near-bottom ΔT's were negative (down to -1.3 F or -0.7C), apparently due to cold water being entrained by the backwash plume (Figure 4.2-7).

Temperature measurements from the boat anchored at Station 6 showed that the west pump's backwash plume arrived within 5 to 10 min of the start of backwashing (Figure 4.2-4). The ΔT's rose sharply to 14.4 F (8.0 C) or an actual temperature of 69.1 F (20.6 C). The resulting thermal plume seemed to be about 2 to 3 ft (0.6 to 0.9 m) thick and persisted for almost 90 min, with highest temperatures of 70.7 F (21.7 C) or 17.0 F (9.4 C) ΔT occurring around 0140 EST after backwashing had been completed. Throughout this time the lower two-thirds of the water column had negative ΔT's down to -2.1 F (-1.2 C) or actual temperatures of 52.5 F (11.4 C) which serves to demonstrate where dilution water was coming from.

Data from Station 15 were less complete due to sampling omission by the vessel observer, but the plume apparently passed between 0030 and 0200 EST (Figure 4.2-5). Along the bottom, ΔT's were negative as at Station 6 (Figure 4.2-4).

Actual backwashing of the west pump was completed around 0113 EST.

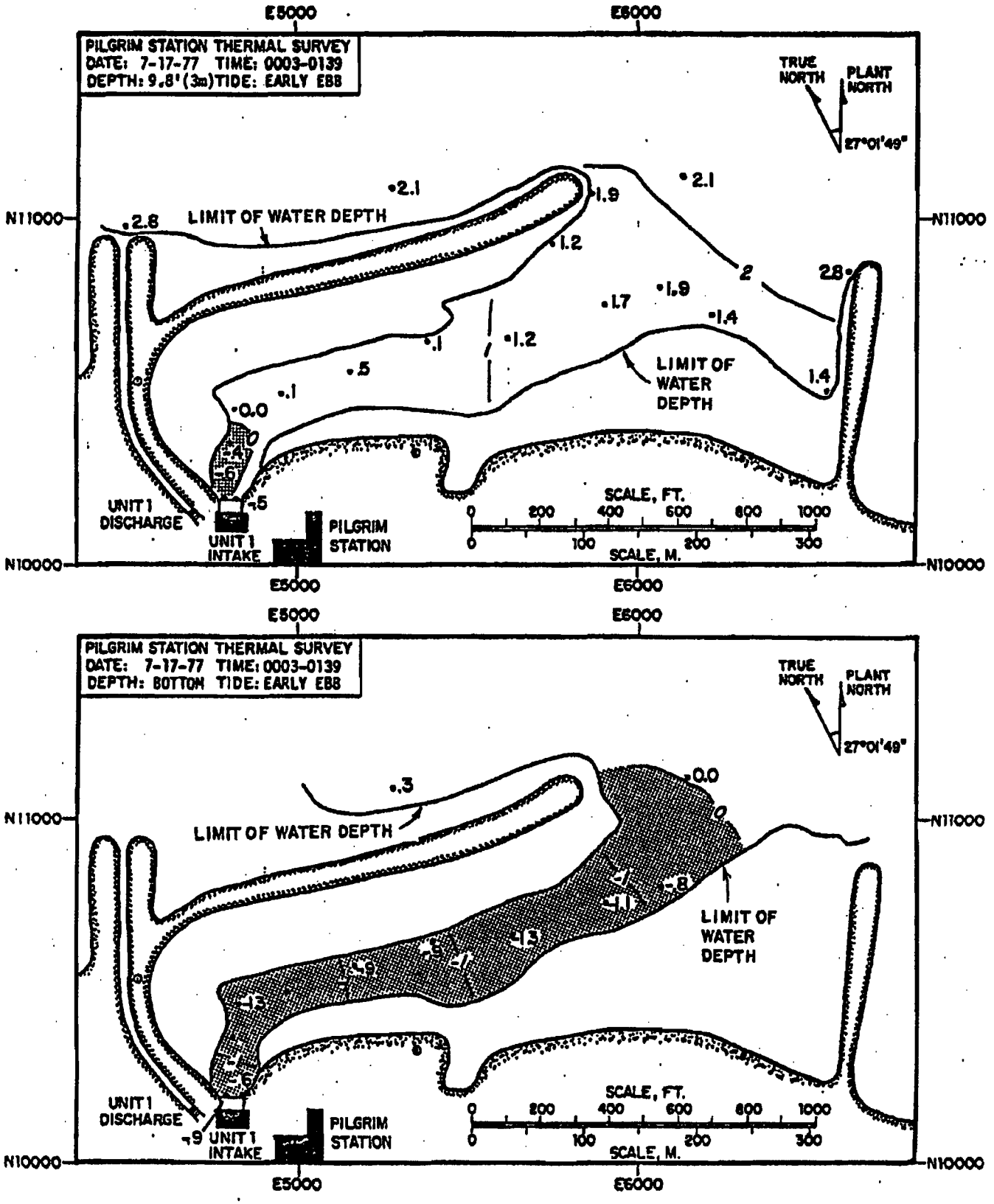

Figure 4.2-7. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during early ebb (backwash west pump) at 9.8 ft (3.0 m) and bottom on July 17, 1977. Pilgrim Station Backwashing Studies, 1977.

4.2.3.3 Mid Ebb (Backwash East Pump)-0140 to 0349 EST

At about 0159 EST backwashing of the east pump started. Actual temperature profiles in front of the intake at Station 1 depicts how the backwashing progressed (Figure 4.2-8). Prebackwashing observations at 0147 EST showed warm water near the surface and as a residual effect from the first backwashing. At 0159 EST backwashing started as a sudden surge of hot water which flowed out of the intake. About 13 min later the backwashing was well along, and near-field thermal plume about 3- to 4-ft thick (0.9 to 1.2 m) had been established.

Surface ΔT's were 43.2 F (24.0 C) in front of the east pump and 25.2 F (14.0 C) in front of the west pump (Figure 4.2-9). Elsewhere ΔT's were generally higher than during the previous sampling run (Figure 4.2-6). Temperature rises of 20 F (11.1 C) and more were found across the channel to the outer breakwater. As before the elevated ΔT's were observed along the outer breakwater (ΔT's of 15 to 20 F or 8.3 to 11.1 C), possibly due to continuing influence of the wind (refer ahead to Figure 4.2-16); however, temperature rises along shore were much higher than before (12.8 to 13.7 F or 7.1 to 7.6 C). Some warm water was observed in the edge of Cape Cod Bay beyond Station 28 due to the transient meteorological conditions at this time of the survey. The exact amount is unknown, but it is estimated that this transient phenomenon was only a small percentage of the backwash thermal plume. At this time the ΔT at the discharge was 15.9 F (8.8 C).

Slightly deeper at 3.3 ft (1.0 m) the temperature distribution was about the same as at the surface (Figure 4.2-9). At most stations actual temperatures or ΔT's were about 3 F (1.7 C) lower, indicating that this was close to the base of the surface plume.

Conditions at 9.8 ft (3.0 m) were much warmer than earlier in the evening with ΔT's ranging from 3.7 and 4.8 F (2.1 and 2.7 C) at the intake to 0.7 F (0.4 C) at Station 28 (Figure 4.2-10). Backwash ΔT's were around 9.1 F (5.1 C). Bottom ΔT's showed a sharp rise too. Conditions ranged from 3.6 F (2.0 C) at Station 2 down to 0.0 at Station 28.

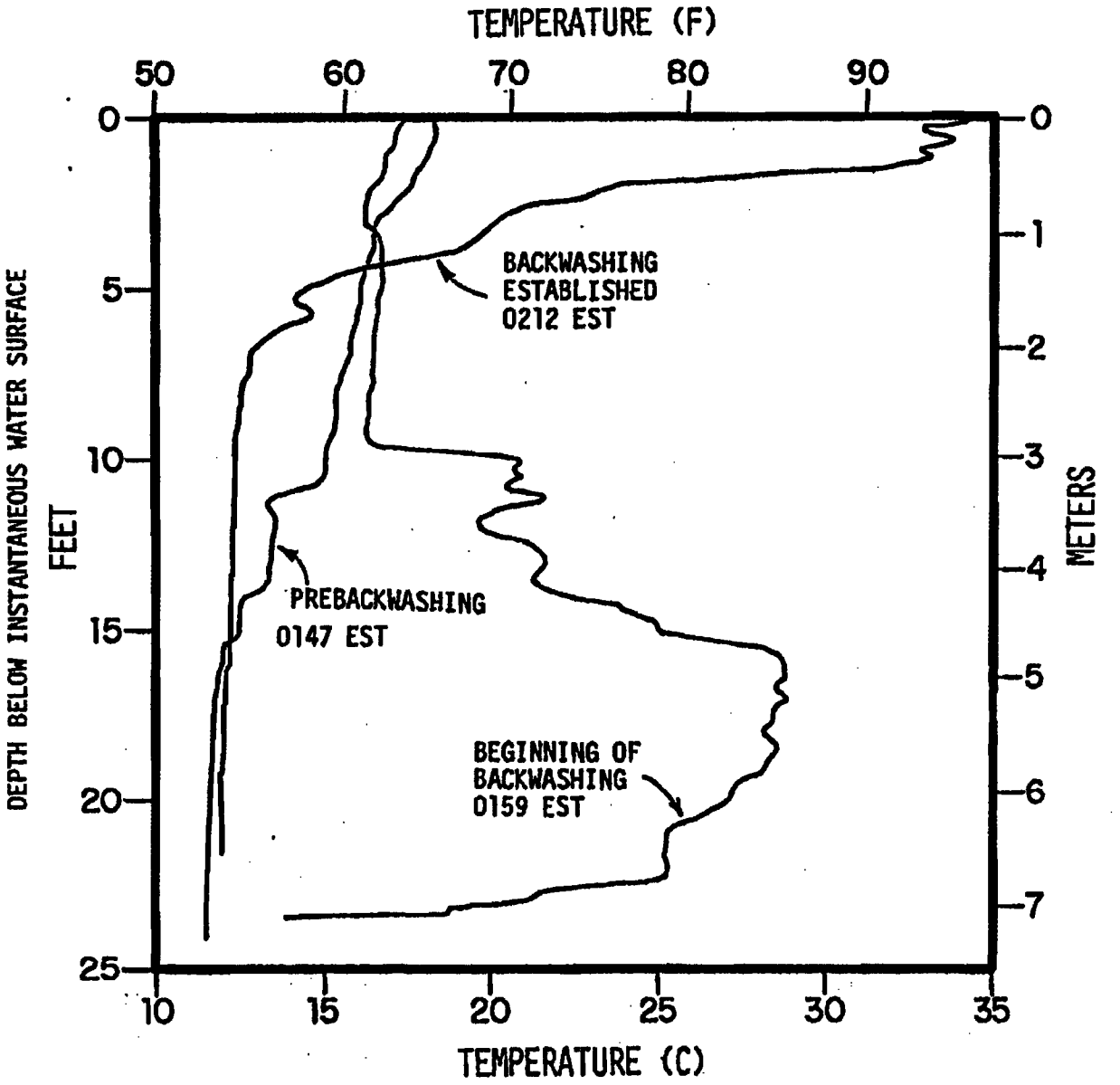

Figure 4.2-8. Temperature profiles from Station 1 during the start of backwashing of the east circulating water pump on July 17, 1977. Pilgrim Station Backwashing Studies, 1977.

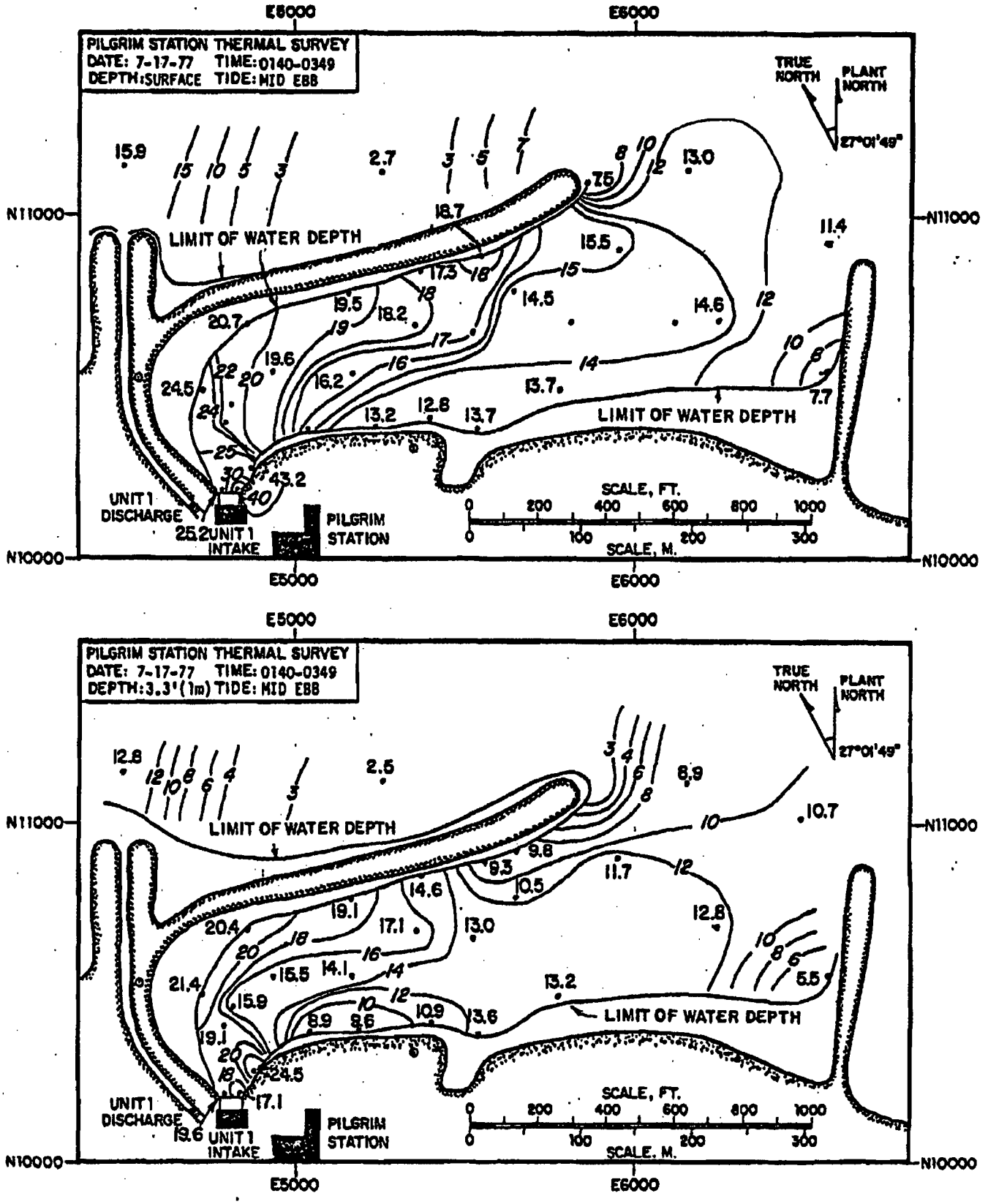

Figure 4.2-9. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during mid ebb (backwash east pump) at surface and 3.3 ft (1.0 m) on July 17, 1977. Pilgrim Station Backwashing Studies, 1977.

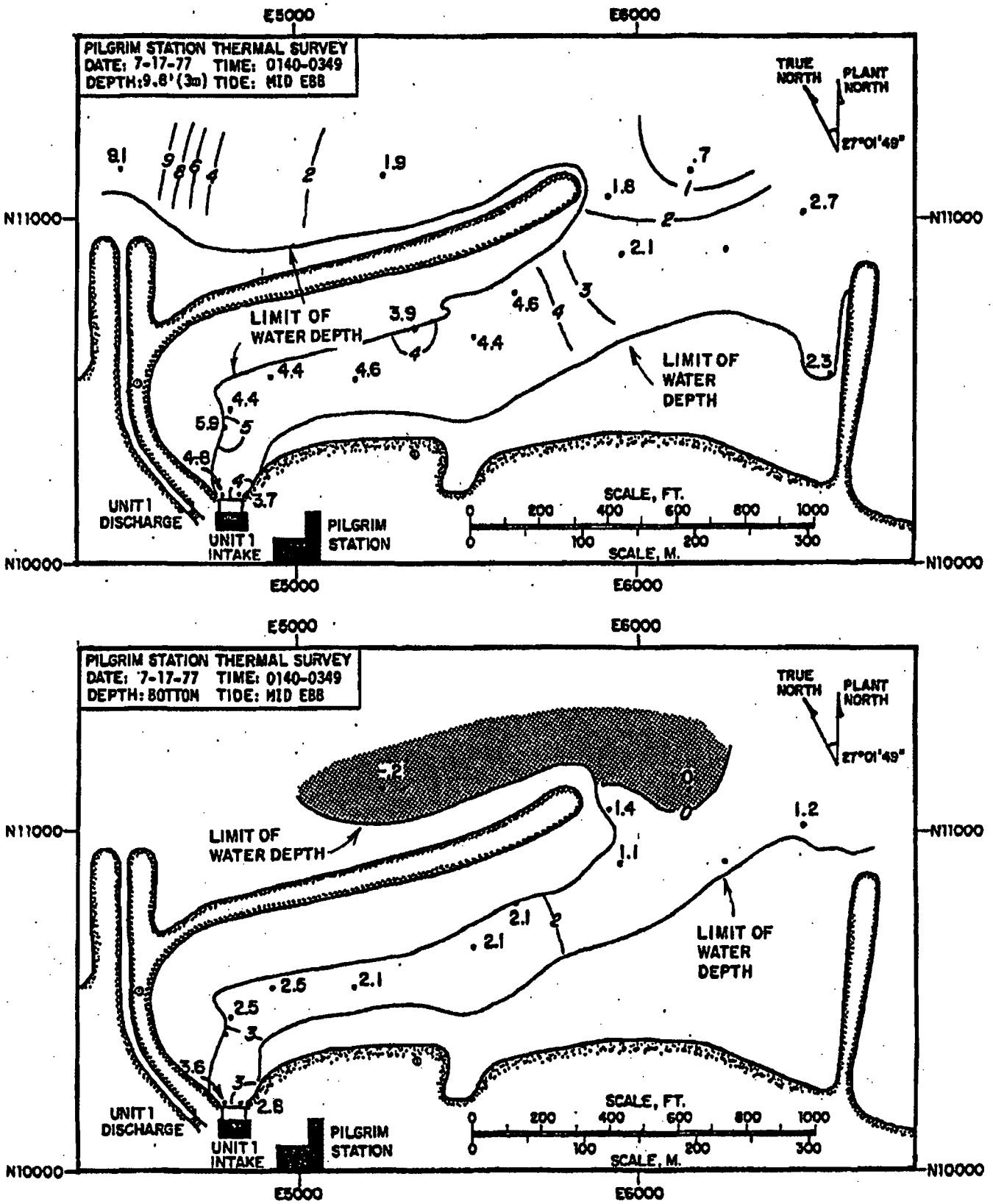

Figure 4.2-10. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during mid ebb (backwash east pump) at 9.8 ft (3.0 m) and bottom on July 17, 1977. Pilgrim Station Backwashing Studies, 1977.

At Station 6, the passage of the east pump thermal plume was very evident (Figure 4.2-4). It took less than 10 min for the backwash water to arrive and, as before, it persisted for about 90 min. The temperatures were slightly higher this time, with the greatest rise occurring at 0320 EST after backwashing was complete (74.4 F or 23.6 C representing a ΔT of 22.9 or 12.7 C). Temperatures at depth also rose, but bottom temperatures became sharply positive.

At Station 15, the second backwash plume was also evidenced but actual temperature rises near the surface are uncertain because of sampling omission by the vessel observer. At depth ΔT's rose considerably up to 5.3 F (2.9 C) at 0220 EST.

At about 0307 EST backwashing of the east pump was completed and the plant started to return to normal operation.

4.2.3.4 Late Ebb (Post Backwash)-0350 to 0517 EST

By the time this survey run began, all backwashing for the evening had been completed. Surface ΔT's provide evidence of residual warm water in front of the intakes (16.8 and 20.9 F or 9.3 to 11.6 C) and out along the western portion of the study area, with ΔT's of 10 to 15 F or 5.6 to 8.3 C (Figure 4.2-11).

Conditions were 8 to 10 F (4.4 to 5.6 C) in front of the plant and 3 to 6 F (1.7 to 3.3 C) out to the outer breakwaters. Some residual warm water apparently from the second backwashing was observed along the breakwater from Stations 13 to 20, forced there by the southwest winds (ΔT's of 12.5 to 16.6 F or 6.9 to 9.2 C). At this time the plant was back in normal operation with ΔT's of 23.4 F (13.0 C) at the discharge.

At 3.3 (1.0 m) ΔT's were 11.8 F (6.6 C) at Station 1 and 8.6 F (4.8 C) at Station 2 in front of the intake (Figure 4.2-11). Warm water was seen along shore at Station 3 (9.6 F or 5.3 C) and up at Station 20

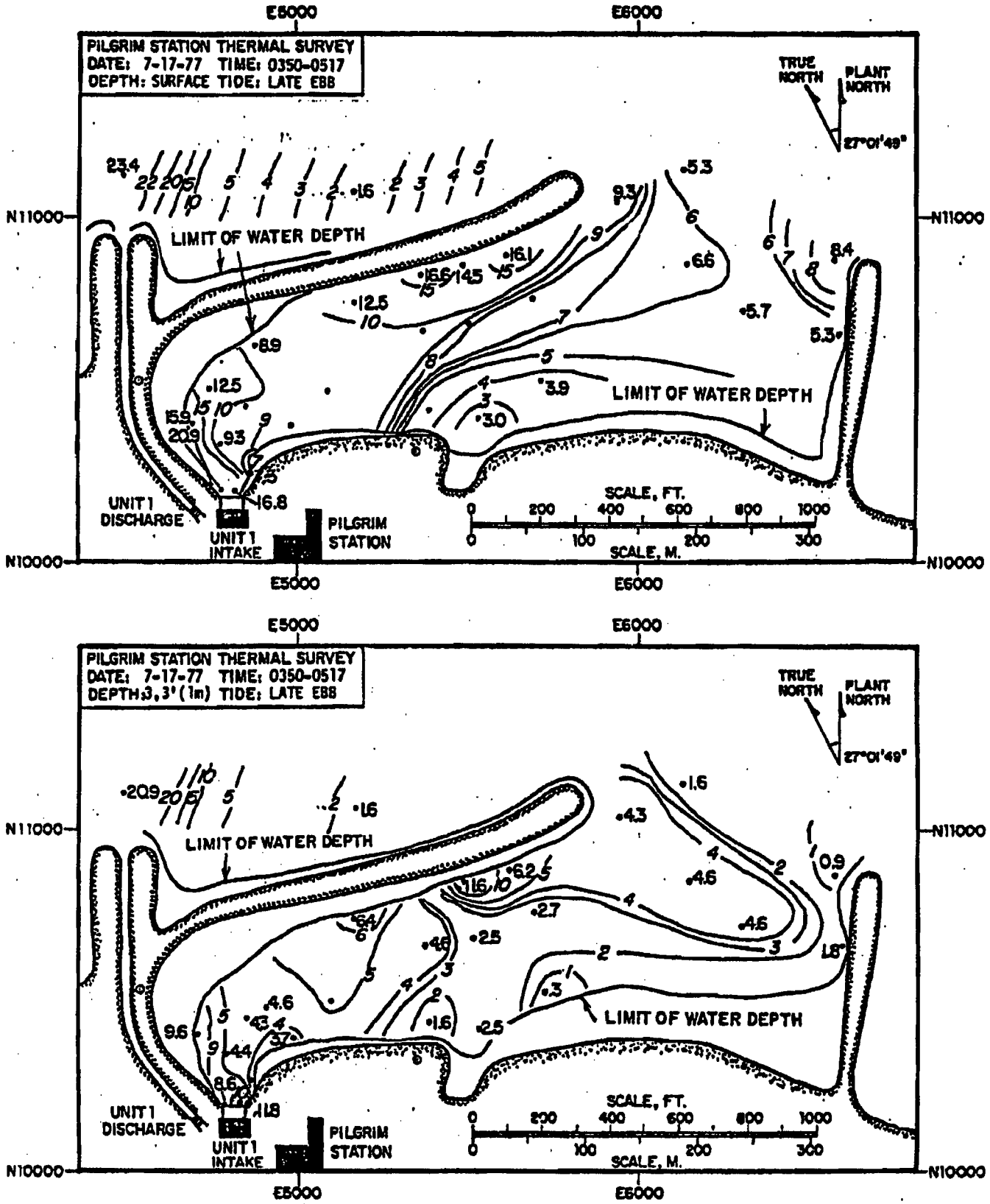

Figure 4.2-11. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during late ebb (postbackwash) at surface and 3.3 ft (1.0 m) on July 17, 1977. Pilgrim Station Backwashing Studies, 1977.

(16.1 F or 8.9 C). Elsewhere ΔT's ranged from 0.3 to 6.4 F (0.2 to 3.6 C) with coldest conditions along shore. At the discharge the ΔT was 20.9 F (11.6 C).

At 9.8 ft (3.0 m) ΔT's in front of the intake were 2.8 and 3.7 F (1.6 and 2.1 C; Figure 4.2-12). About halfway along the channel they were 1.0 to 2.0 F (0.6 to 1.1 C). Further from the intake ΔT's were 1.0 F (0.6 C) or less. On the bottom they were still slightly warm in front of the intake (1.4 F or 0.8 C), but elsewhere they were close to 0 or slightly negative.

At Station 6 temperature conditions had again stabilized after the backwashing. Surface temperatures were 55.7 to 56.6 F (13.2 to 13.7 C) representing ΔT's of 3.2 to 4.1 F (1.8 to 2.3 C). Bottom tmperatures were 51.5 to 53.1 F (10.8 to 11.7 C) or negative ΔT's of up to -1.4 F (-0.8 C).

Further from the intake at Station 15, the temperatures remained slightly warmer with ΔT's of 4.0 to 8.0 F (2.2 to 4.4 C) in the upper part of the water column and near 0.0 along the bottom (Figure 4.2-5).

4.2.3.5 Low Water (Survey Complete)-0518 to 0538 EST

At this time the plant had resumed normal operations and all traces of hot backwash water were gone. Surface ΔT's were 4.3 F (2.4 C) at Station 1 and 1.2 F (0.7 C) at Station 2 (Figure 4.2-13). At Stations 6 and 15 ΔT's were around 3.2 F (1.8 C). Slightly deeper at 3.3 ft (1.0 m) ΔT's were 1.0 to 2.1 F (0.6 to 1.2 C) near the intake and 0.6 to 3.7 F (0.3 to 2.1 C) at Stations 6 and 15. At 9.8 ft (3.0 m) the ΔT's ranged from -0.1 to 1.2 F (-.06 to 0.7 C; Figure 4.2-14).

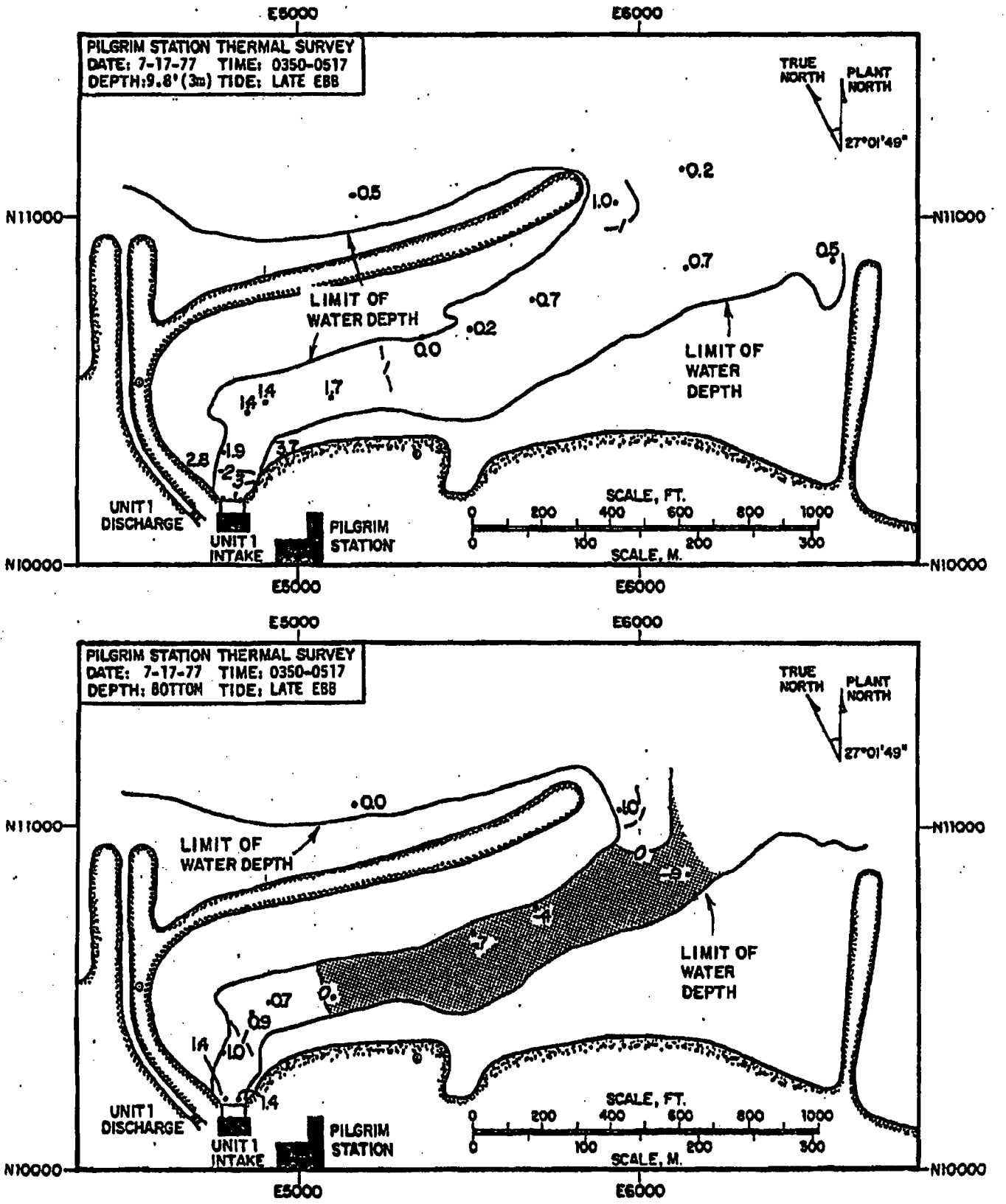

Figure 4.2-12. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during late ebb (post-backwash) at 9.8 ft (3.0 m) and bottom on July 17, 1977. Pilgrim Station Backwashing Studies, 1977.

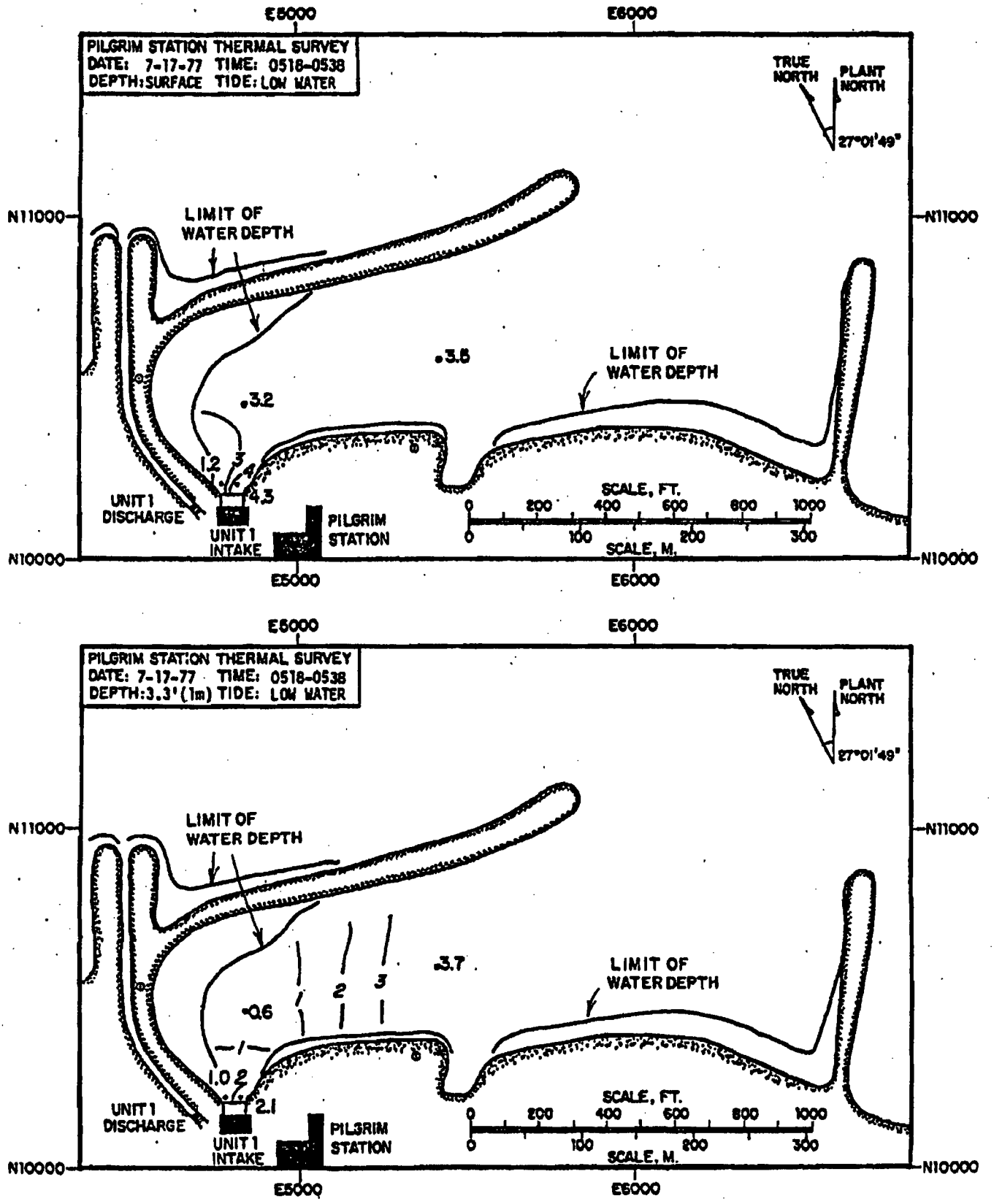

Figure 4.2-13. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during low water (survey complete) at surface and 3.3 ft (1.0 m) on July 17, 1977. Pilgrim Station Backwashing Studies, 1977.

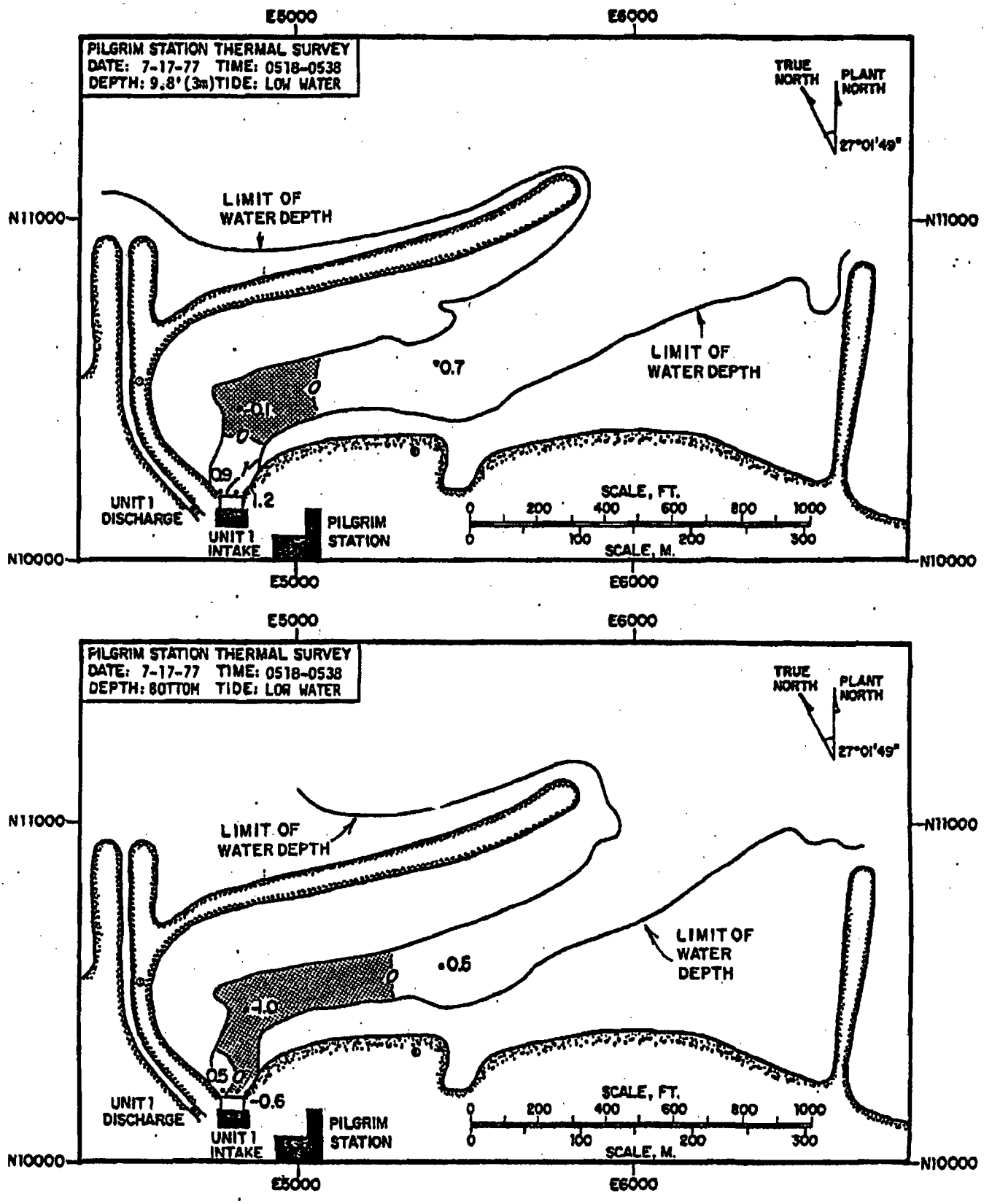

Figure 4.2-14. Contour maps of observed temperature rises (ΔT) in degrees F above ambient during low water (survey complete) at 9.8 ft (3.0 m) and bottom on July 17, 1977. Pilgrim Station Backwashing Studies, 1977.

Finally along the bottom, temperatures ranged from -1.0 F (-0.6 C) at Station 6 to 0.5 F (0.3 C) at Stations 2 and 15. As noted previously; temperature conditions had stabilized at Stations 6 and 15 (Figures 4.2 -4 and 4.2-5).

4.2.3.6 Summary

The elevated surface temperatures and thermal backwashing plumes persisted for almost 4 hrs in the western portion of the study area and somewhat less in the eastern portion, before dissipating. Wind seemed to play a role in forcing the hot water along the outer breakwater and keeping it away from the shore in front of Unit 1.

4.2.4 CURRENTS

Flow patterns in the study area were again dominated by plant operation, as they were during the July 9 and 10, 1977 survey (Figure 4.2-15). Currents at both Stations 1 and 6 were southward or into the plant at 0.1 to 0.37 kn throughout the survey,, except for during actual backwashing. As before, backwashing caused a shearing in the water column, with near-bottom currents continuing to flow toward the intake, vertical flow near the screenwall and near-surface currents (up to 0.2 kn) flowing seaward. Once the hot backwash plume was established at the surface, continued pumping carried it out toward Cape Cod Bay. Flows at stations further from the plant were still dominated by drawing of the intake system, but wind stress from the strong southwest winds helped force the hot water seaward during much of the night.

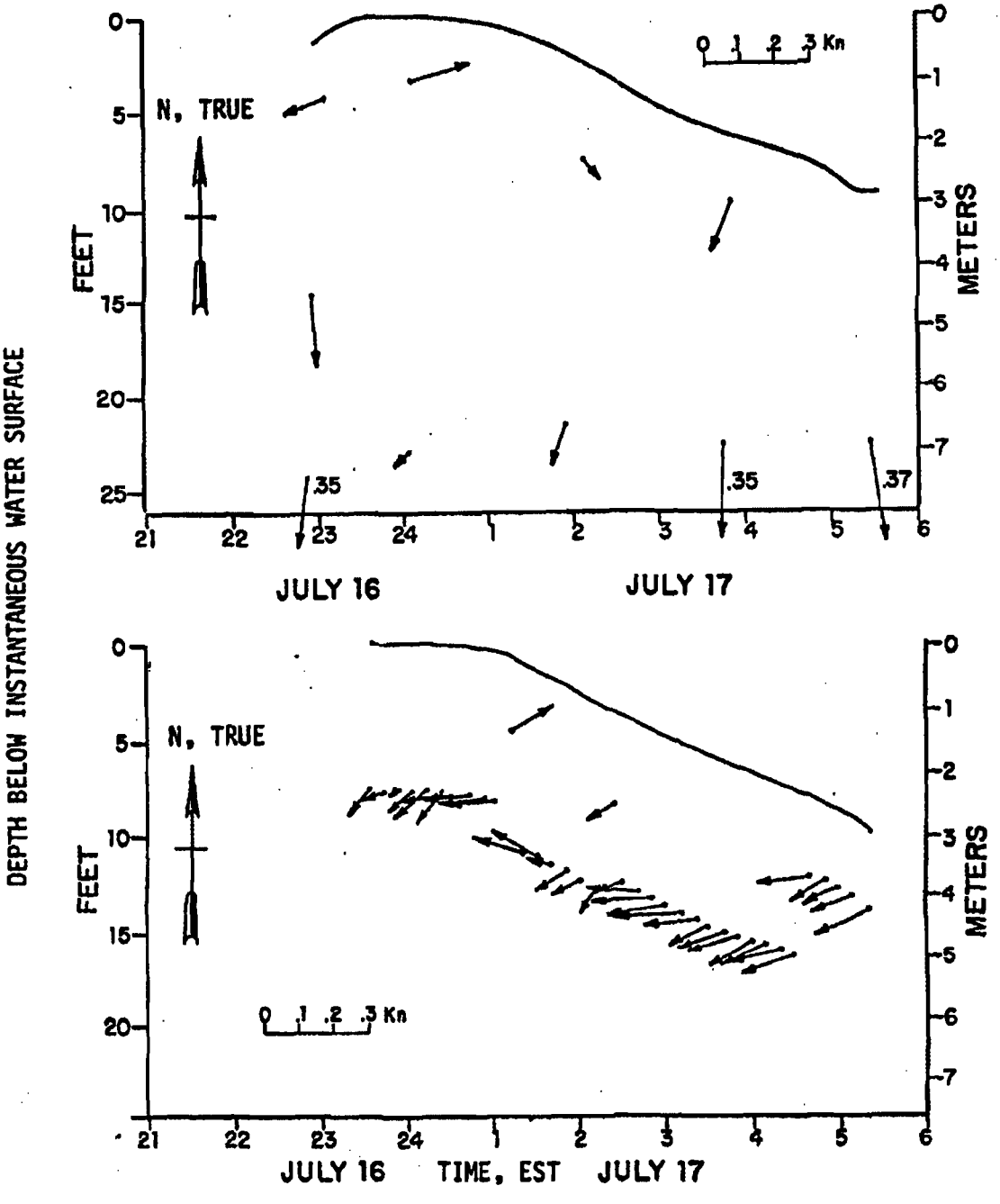

Figure 4.2-15. Vector plots of current measurements in degrees true (referenced toward which currents were flowing) and kn from Station 1 (upper) and Station 6 (lower) on July 16 and 17, 1977. Pilgrim Station Backwashing Studies, 1977.

4.2.5 AIR TEMPERATURE

Air temperature measurements at the 33-ft (10-m) level on Boston Edison Company's 160 ft (48.8 m) meteorological tower (Figure 2.1-1) showed a gradual warming during the day to about 83 F (28.3 C) at 1800 EST (Figure 4.2-16). During the night temperatures dropped gradually to a low of about 73 F (22.7 C) but humidity remained very high. Starting at dawn temperatures rose sharply to 89.5 F (31.9 C) by noontime.

4.2.6 WIND CONDITIONS

Wind speed and direction measurements at the 33-ft (10-m) level on Boston Edison Company's 160 ft (48.8 m) meteorological tower indicated the presence of light winds from the southeast until early evening (Figure 4.2-16). At about 1800 EST, the wind shifted to southwesterly and intensified. Wind speed was steady at 12 to 15 mph all night. These winds may have helped carry the backwash plume out along the outer breakwater and forced some hot water into Cape Cod Bay.

4.2.7 TIDES

Tide observations generally showed good agreement with NOAA-NOS tide predictions (Figure 4.2-17). Although data were incomplete, it appears that the early morning low tide was slightly lower than predicted.

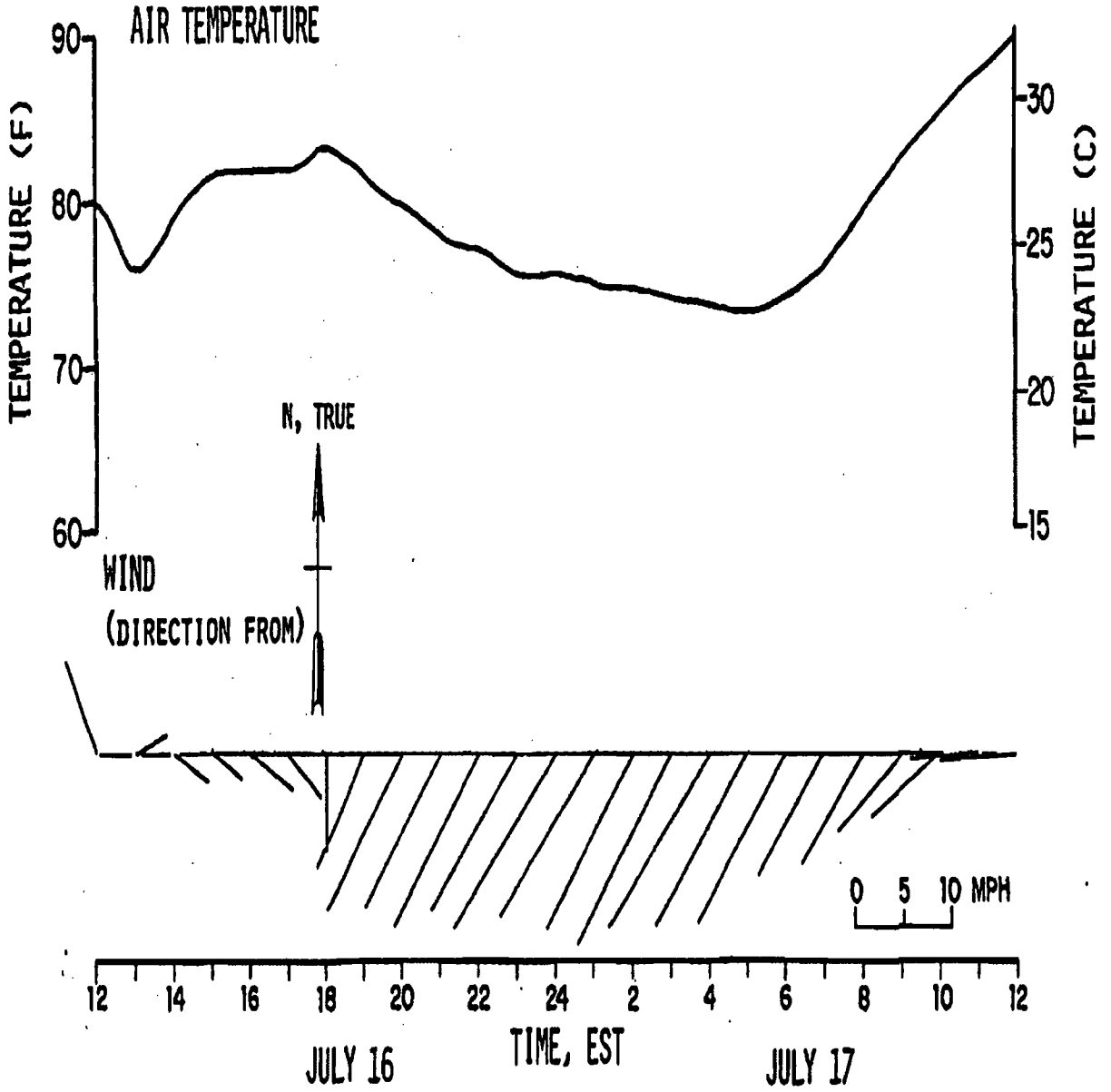

Figure 4.2-16. Air temperature and wind vector plots in degrees true (referenced toward which wind was blowing) and mph from the 33 ft (10 m) level of the Boston Edison Company meteorological tower on July 16 and 17,1977. Pilgrim Station Backwashing Studies, 1977.

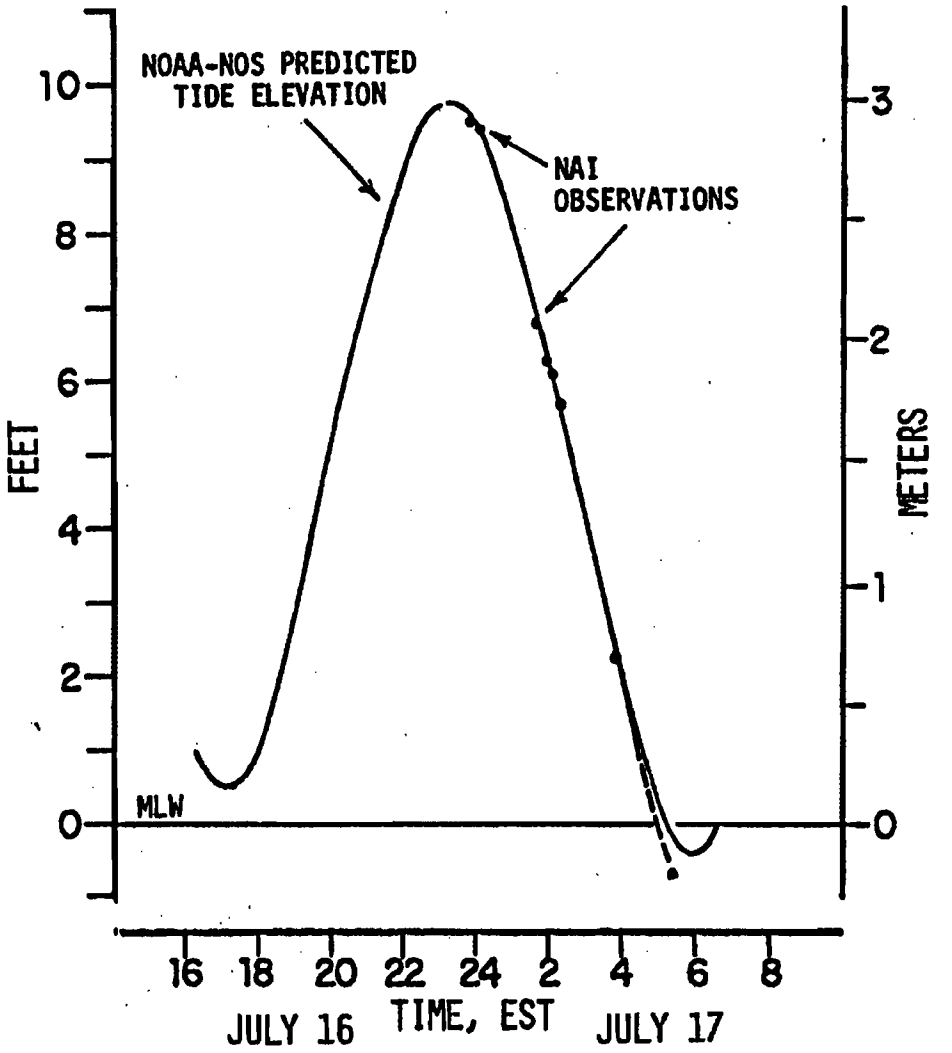

Figure 4.2-17. Plot of NOAA-NOS predicted tide elevations for the Pilgrim Station area along with NAI tide observations for July 16 and 17, 1977. Pilgrim Station Backwashing Studies, 1977.

5.0 DISCUSSION

5.1 PLUME DYNAMICS

In general the dynamics of the backwash plume were quite similar during each of the survey weekends. Backwashing was first evidenced by a pulse of hot water at depth from the intake (Figure 4.2-8). As the pumping continued, the buoyant hot water rose to the surface. Within a few minutes it formed a highly stratified thermal plume averaging 3 to 5 ft (0.9 to 1.5 m) in thickness. During the first weekend survey, the thermal plume formed a distinct frontal zone of foam and turbulent, steaming water which could be easily tracked by eye. Under the influence of the reverse intake flows, the initial jet momentum, the plume buoyancy effect and the localized hydrostatic head in front of the screenwall, the frontal zone moved slowly across the study area. Along shore and in shallow water, frictional effects slowed the frontal zone, causing the plume to take on a bulge in the center. The hot water propagated toward the western portion of the study area and the outer breakwater; but relatively little hot water contacted the shoreline area in front of Unit 1 during both of the surveys. During the second survey the frontal zone behaved in a similar manner; but was much less distinct, possibly because of the increased volume of receiving water (high water condition). The difference between high water and low water in front of the intake can be readily seen from the photographs in Figure 5.1-1.

5.2 TEMPERATURE RISES

During the first weekend, backwashing was coincident with low-water and early flood conditions when receiving water volumes were minimal. Each actual backwashing lasted from 37 to 49 min. Maximum surface temperatures of 100.9 F (38.3 C) were observed in front of the intake, representing a ΔT of 43.4 F or 24.1 C.

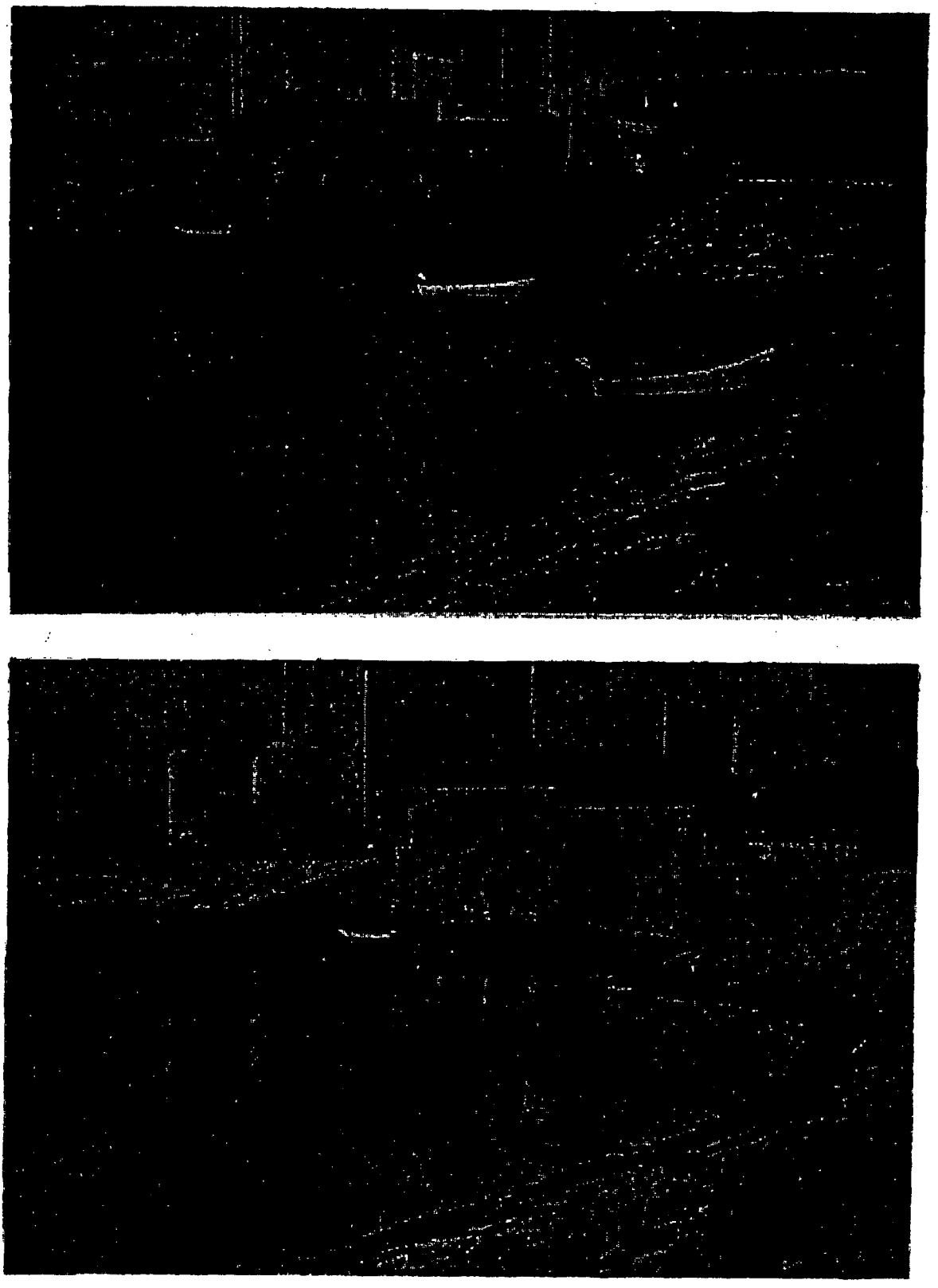

Figure 5.1-1. Photographs of the western portion of the study area in front of the Pilgrim Station intake at high water (upper) and low water (lower). Pilgrim Station Backwashing Studies, 1977.

At Station 6, two distinct pulses of hot water from each backwashing were observed, with maximum surface temperatures of 79.0 F (26.1 C) and 81.1 F (27.3 C), respectively (Figure 4.1-4). Thus, temperatures had dropped substantially within less than 200 ft (61 m) of the intake. Based on arrival times, it appears that the front moved out at about 0.2 kn, which was consistent with current-meter measurements. Further seaward at Station 15, similar pulses were observed about 30 to 40 min after backwashing started. Actual surface temperatures were even lower than at Station 6 (77.0 F or 25.0 C and 75.8 F or 24.3 C for each backwash, respectively; Figure 4.1-5). During the first weekend the hot water required about 2 to 2.5 hrs. to dissipate.

During the second weekend when backwashing was coincident with high water and early ebb, receiving water volumes were close to maximum. Each of these backwashes lasted longer than before (58 to 73 min) but the plant backwash operational temperature remained about the same. Apparently, due to the increased volume of available diluting or receiving water, maximum observed surface temperatures in front of the intake were only 94.9 F (34.9 C), representing a ΔT of 43.2 F or 24.0 C. The frontal zone moved out at about 0.2 kn, as it had the preceding weekend.

At Station 6, two pulses of hot water from backwashing were observed. The first reached 70.7 F (21.5 C) whereas the second was up to 74.4 F (23.6 C). Similar pulses were observed at Station 15 but maximum surface temperatures attained are unknown due to sampling omission. During the second weekend it took much longer for the hot water to dissipate than the first weekend (nearly 4 hrs), probably because each backwash lasted longer (Figure 4.2-1).

5.3 EFFECT OF WIND ON PLUME MOVEMENT

Because of the relative thinness of the thermal plume and the pronounced stratification it created, it appeared to be highly susceptible to wind shear effects. During both weekend surveys, southwesterly winds forced much of the plume against the outer breakwater, leaving the shoreline area much less affected. During the second weekend some hot water was apparently forced out into Cape Cod Bay beyond the outer breakwater by transient wind effects (estimated to be only a small percentage of the surface backwash thermal plume). In general, the eastern portion of the study area remained relatively unaffected by the hot water during both studies. Where the thermal plume impinged the shoreline, such as along the breakwaters, it was generally less than 2 ft (0.6 m) thick.

5.4 AMBIENT VARIABILITY

The observed near-bottom ambient temperature variations at the reference Station 28 agree with historical data from these waters (Stone and Webster, 1975). The warming trend observed at this location on July 9 and 10 suggests that some water from the discharge can recirculate into the intake area.

6.0 SUMMARY AND CONCLUSIONS

Based on the two weekend surveys of actual backwash operations at Pilgrim Station under varying tidal conditions, the following conclusions have been reached:

1. During a typical backwashing operation, plant water box temperatures are generally held at 90 to 98 F (32.2 to 35.7 C) for 45 to 60 min depending upon how fouled the condenser tubes are. Toward the end of the cycle even higher temperatures of up to about 120 F (48.9 C) may occur for 10 to 15 min. Backwash temperatures on the west pump sometimes are run slightly higher than on the east pump because fouling there tends to be greater and more heat treatment is required.

2. Backwashing was first evidenced by a pulse of hot water issuing from the intake at depth. As the pumping continued, the buoyant hot water rose to the surface. Within a few minutes of inception, it formed a highly stratified thermal plume averaging 3 to 5 ft (0.9 to 1.5 m) in thickness. During the first weekend the thermal plume formed a distinct frontal zone of foam and turbulent, steaming water which could be easily tracked by eye. Under the influence of the reverse intake flows and the localized hydrostatic head in front of the screenwall, the frontal zone moved slowly across the study area. During the second survey the frontal zone behaved in a similar manner but was much less distinct, possibly because of increased volume of receiving water at high tide.

3. During the first weekend, backwashing was keyed to low-water and early flood conditions when receiving water volumes were minimal. Each actual backwashing lasted from 37 to 49 min. Maximum surface temperatures of 100.9 F (38.3 C) were observed in front of the intake,

representing a ΔT of 43.4 F or 24.1 C. During the second weekend when backwashing was keyed to high water and early ebb, receiving water volumes were close to maximum. Each of these backwashes lasted longer than before (50 to 73 min) but the plant backwash operational temperature remained about the same. Apparently due to the increased volume of available diluting or receiving water, maximum observed surface temperatures in front of the intake were only 94.9 F (34.9 C), representing a ΔT of 43.2 F or 24.0 C.

4. Profile data from anchored boats at Stations 6 and 15 showed distinct pulses of hot water from each backwashing. Generally the frontal zone arrived at Station 6 within 5 to 10 min and at Station 15 within 30 to 40 min. Based on arrival times, it appears that the front moved out at about 0.2 kn,which was consistent with near-surface current-meter measurements.

5. Along shore and in shallow water, frictional effects slowed the frontal zone,causing a bulge in the center. During both surveys, the hot water propagated towards the western portion of the study area and the outer breakwater; but relatively little hot water was seen to affect the shoreline area in front of Unit 1 and the coast toward the east. Heat was lost very rapidly as the thermal plume moved seaward, as evidenced by temperature drops at Stations 6 and 15 which were progressively further from the intake. During the first weekend the hot water required about 2 to 2.5 hrs to dissipate. During the second weekend when backwashing lasted a little longer, it required nearly 4 hrs for the hot water to dissipate.

6. The thermal plume was thickest close to the intake screen wall (5 to 6 ft or 1.5 to 1.8 m at times); but, along its distal edges it thinned rapidly, often to 1 ft (0.3 m) or less right along shore.

7. Because of the relative thinness of the thermal plume and the pronounced stratification it created, it appeared to be highly susceptible to wind-shear effects. During both weekend surveys, southwesterly winds forced much of the plume against the outer breakwater, leaving the shoreline area much less affected. The second weekend some hot water was apparently forced out into Cape Cod Bay beyond the outer breakwater by the wind (estimated to be no more than 5% of the maximum near-surface backwash thermal plume). In general, the eastern portion of the study area remained relatively unaffected by the hot water during both studies.

8. In summary the backwashing operation caused a relatively thin thermal plume which spread rapidly across the western portion of the study area and along the outer breakwater. Within a few hours it was completely dissipated.

7.0 REFERENCES

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Normandeau Associates, Inc. 1976a. Physical Sciences Data Processing Technical Procedures Manual 5.0.

_____. 1976b. Physical Sciences Equipment and Instrumentation Technical Procedures Manual 3.0.

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_____. 1977. Proposal to conduct hydrothermal surveys of backwashing operations at Pilgrim Station for Boston Edison Company.

Stone and Webster Engineering Corporation. 1975. 316 Demonstration Pilgrim Nuclear Power Station Units 1 and 2 Boston Edison Company.

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Craver, Patti

From: Balsam, Briana NRC
Sent: Thursday, April 12, 2012 1:01 PM
To: Julie Crocker
Subject: RE: Pilgrim: NRC's complete responses to 4-9-12 NMFS questions
Attachments: ENSR 2000 316 Demonstration.zip

Reference 4 of 4.

From: Balsam, Briana
Sent: Thursday, April 12, 2012 12:56 PM
To: 'Julie Crocker'
Cc: Logan, Dennis; Susco, Jeremy; Smith, Maxwell; 'jegan1@entergy.com'
Subject: Pilgrim: NRC's complete responses to 4-9-12 NMFS questions

Julie,

I attached the NRC's completed responses to the questions on Pilgrim that you sent in your April 9 email to follow-up on our partial response dated April 10.

I will also be forwarding several zip files containing the documents referenced in the responses in subsequent emails. I tried to send them all as one zip folder, but it seems as if my agency's email attachment size limit is a bit higher than yours—the last email I was able to send, but it came back undeliverable. All of the references should also be publically available in our ADAMS system also, and I have included the accession number for each in the attached responses, so that would be another way for you to access those documents if email doesn't work.

Briana

Briana A. Balsam
Biologist

Division of License Renewal
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission

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