TECHNICAL REPORT

PT. THOMSON UNIT 1999 PHYSICAL OCEANOGRAPHY/ METEOROLOGY BASELINE STUDY

Prepared for
BP AMOCO

and

Pt. Thomson Unit Owners

April 27, 2000

URS

URS CORPORATION
3501 Denali St., Suite 101
Anchorage, Alaska 99503
74-09900007.00

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BP AMOCO and its lease partners are currently evaluating coastal petroleum reservoirs for commercial development in the Point Thomson Unit. Foreseeable development may include a gravel-fill dock extending to the 10-foot (ft) isobath, coastal well pads, a central process facility, an in-field road and a pipeline system, an airstrip, and a transportation pipeline connecting with the Badami pipeline. Federal permits will be required to construct the proposed development; thus, an environmental impact analysis will be completed based on procedures enacted by the National Environmental Policy Act (NEPA) of 1969.

BP AMOCO initiated several studies to collect area wide or regional data sets, since there was a lack of available physical environment and ecology data for the Point Thomson Unit to support a NEPA analysis. URS Greiner Woodward Clyde (1999) conducted the first of the regional physical oceanography studies in 1997 and 1998. The goal of the studies was to collect regional baseline information on the physical environment such that potential habitat alteration and wildlife disturbance could be evaluated during the NEPA analysis. As conceptual engineering design matured, preliminary siting of coastal structures was identified and site-specific environmental studies were designed to describe baseline (pre-development) conditions.

This report presents the findings of the 1999 physical oceanography/meteorology study conducted in the vicinity of Pt. Thomson and Mary Sachs Entrance (Figure 1.1). The study was designed to collect site-specific pre-development baseline hydrography (water column temperature and salinity) for the area possibly affected by placement of a gravel-filled docking structure near Pt. Thomson. Regulatory community concerns regarding the water column characteristics immediately adjacent to the shoreline were also addressed in this study.

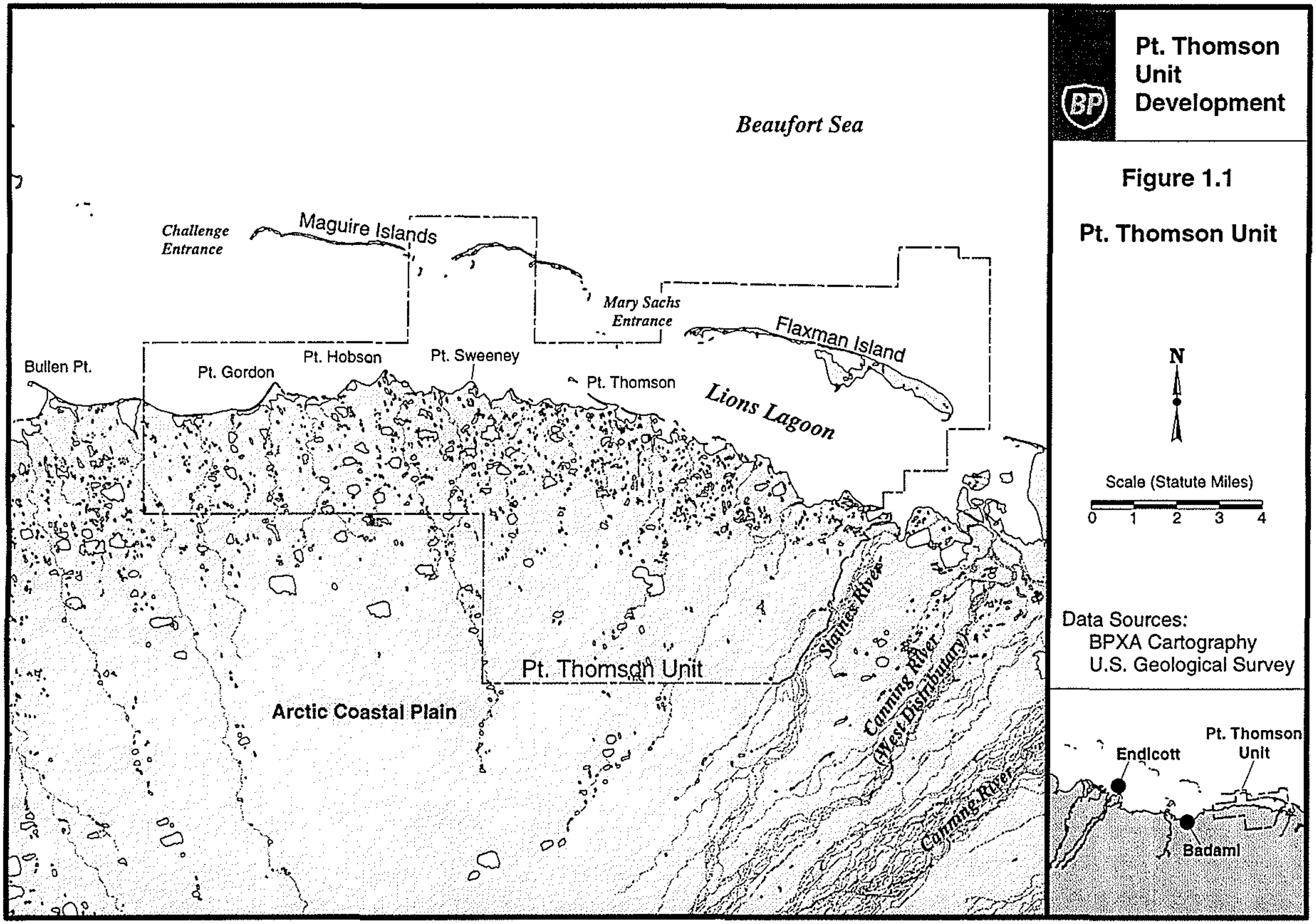

Figure 1.1

Pt. Thomson Unit

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2.1 BACKGROUND

Physical oceanography studies were conducted within Lions Lagoon to confirm that regional processes observed throughout the nearshore Beaufort Sea controlled the water movement and water column structure within the lagoon system (Kinnetic Laboratories, Inc. 1983, URS Greiner Woodward Clyde 1999). The URS Greiner Woodward Clyde (1999) study determined that:

- Local freshwater input from the Staines and Canning rivers created brackish water conditions for lagoon waters south of Flaxman Island. The lack of notable fresh water was evident along the western portion of Lions Lagoon.
- Upwelled marine bottom waters entered the lagoon system through the channels between the barrier islands during persistent easterly winds that also depressed the water level.
- Elevated water levels corresponded to persistent westerly winds and short (24- to 36-hour) periods of mixed easterly and westerly winds. Typically, uniform brackish ($\leq$25 part per thousand [‰]) conditions were observed throughout Lions Lagoon during these events.

The geometry of the lagoon system influenced water movement and water quality. Specific observations included:

- The channels between the barrier islands served as pathways for Beaufort Sea shelf and marine waters to enter Lions Lagoon during easterly winds.
- Current direction within Mary Sachs Entrance and Flaxman Pass was parallel to the channel.
- The barrier island complex effectively protected lagoon waters. Turbidity and suspended sediment were elevated for waters adjacent to the Staines and Canning rivers and in the channels between the barrier islands.

2.2 PROGRAM OBJECTIVES

The 1999 physical oceanography/meteorology study was based on the present understanding of lagoon waters and the influence of regional physical oceanographic processes for the nearshore Beaufort Sea. The study objectives were:

- Observe nearshore (lagoon) water column temperature and salinity (hydrography) immediately adjacent to the proposed dock structure during the summer, open-water season
- Observe surf-zone (shore to 100 meters offshore) water column temperature and salinity (hydrography) immediately adjacent to the fyke nets associated with the fisheries study
- Collect meteorological data that represent site conditions. Parameters include wind velocity (speed and direction), air temperature, and barometric pressure.
- Verify that regional physical oceanographic and meteorological processes influence the characteristics of the nearshore water column structure.
- Supplement the 1997 and 1998 regional physical oceanography and meteorological data sets with site-specific information.

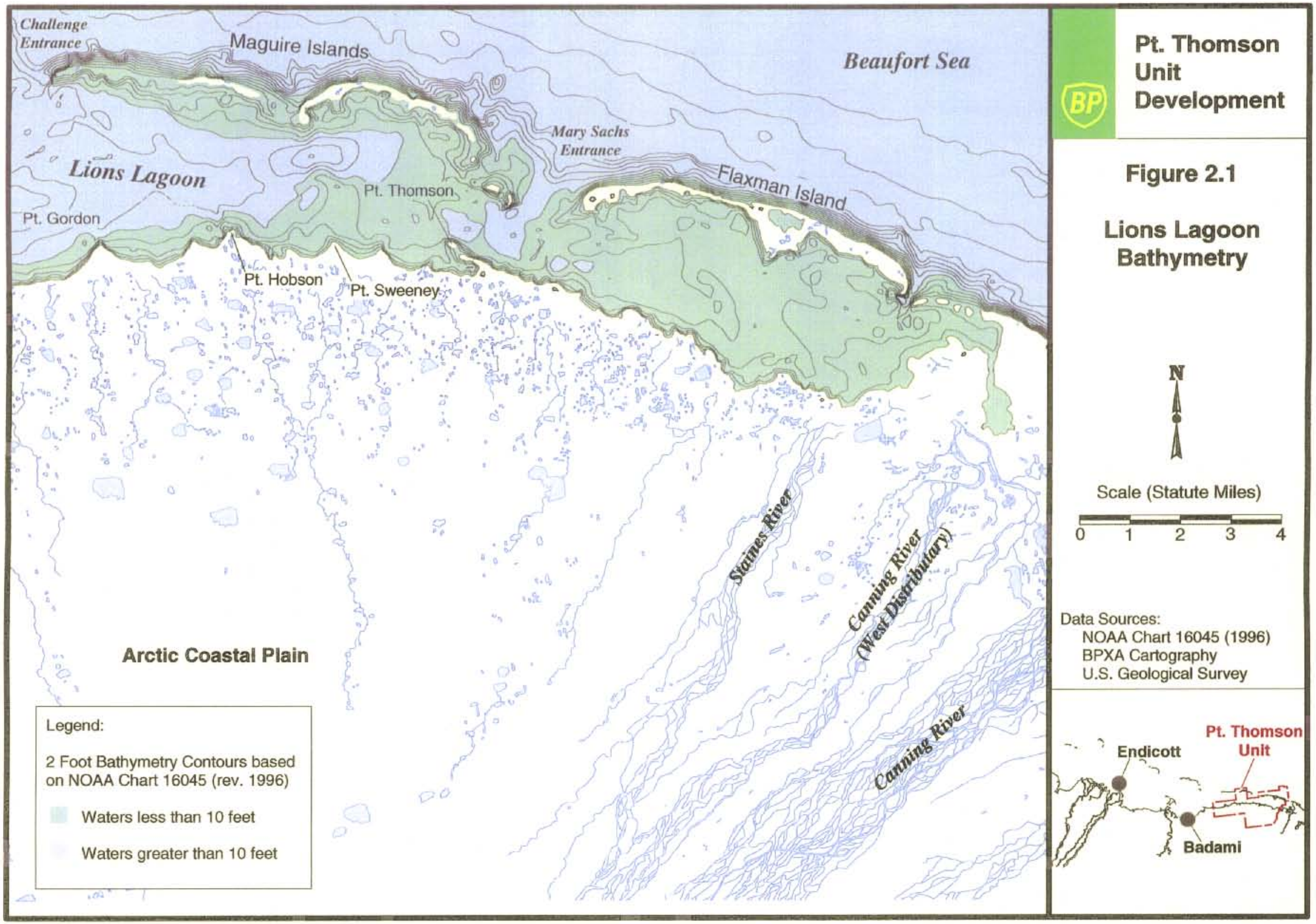
2.3 STUDY AREA

The barrier island complex shelters much of Lions Lagoon from exposure to storm waves generated in the Beaufort Sea during open-water periods. The lagoon is divided by the Mary Sachs Entrance, a broad 2.25-mile pass between North Star and Flaxman islands. The lagoon east of the Mary Sachs Entrance is shallow and is protected by Flaxman Island, while west of the Mary Sachs Entrance is a deeper and wider lagoon that is open at the west end.

The eastern third of the lagoon is shallow, with depths generally less than 10 ft. Shoals are common near the mouth of the Staines River and western distributary of the Canning River and extend toward Point Brownlow. The channel between the east end of Flaxman Island and Point Brownlow (Flaxman Pass) is narrow (1,200 ft) and relatively deep (26 ft). Historical soundings obtained from NOAA Chart No. 16045, revised in 1996, suggest the lagoon is asymmetrical, with deeper waters near the mainland shore and a gentle slope from mid-channel north to Flaxman Island (Figure 2.1). Water depths within the lagoon gently increase towards the west to a depth of 8 ft approximately mid-length of Flaxman Island and reach 11 ft immediately northeast of Point Thomson.

Mary Sachs Entrance is a broad and relatively deep channel, with an northeast/southwest-oriented channel that extends toward Point Thomson. Water depths within the channel are typically 9 to 11 ft with the 10-ft isobath approximately 2,400 ft north of the mainland shore in the vicinity of Point Thomson. Mary Sachs Entrance provides a break in the protection offered by the barrier islands, exposing the shoreline adjacent to and east of Point Thomson to offshore storm events. The increased exposure to waves is evidenced by the well-developed spit and bar formation along the mainland shore.

The western portion of the lagoon is protected by a group of barrier islands known as the Maguire Islands (Challenge, Alaska, Duchess, and Northstar islands). This portion of the lagoon widens from 1.5 miles at Point Thomson to 3.5 miles near Challenge Island. Water depths adjacent to the mainland between Point Thomson and Point Hobson are typically 7 to 10 ft and gently increase to 16 ft at the west end of the lagoon.


Challenge Entrance
Maguire Islands
Beaufort Sea
Mary Sachs Entrance
Lions Lagoon
Pt. Thomson
Flaxman Island
Pt. Gordon
Pt. Hobson
Pt. Sweeney
Staines River
Canning River (West Distributary)
Canning River
Arctic Coastal Plain
Legend:
2 Foot Bathymetry Contours based on NOAA Chart 16045 (rev. 1996)
Waters less than 10 feet
Waters greater than 10 feet
BP
Pt. Thomson Unit Development
Figure 2.1
Lions Lagoon Bathymetry
N
Scale (Statute Miles)
0 1 2 3 4
Data Sources:
NOAA Chart 16045 (1996)
BPXA Cartography
U.S. Geological Survey
Endicott
Pt. Thomson Unit
Badami

3.1 DATA COLLECTION

Throughout the summer open-water season, LGL Research Associates maintained a field crew at the mothballed drilling camp located on the Pt. Thomson Unit #1 pad. Established in early July, the camp was operational until breakdown on August 27, 1999. The Point Thomson Unit Oceanography/Meteorology Study consisted of:

- 20 hydrography (water column temperature and salinity) surveys in the shallow coastal waters surrounding the currently proposed gravel-fill dock site for the Pt. Thomson Unit Development
- Establishing and maintaining a meteorology station east of Point Thomson for the duration of the study.

3.2 HYDROGRAPHY

At each sample station, a Sea-Bird Electronics, Inc. Model SBE-19 conductivity-temperature-depth (CTD) instrument was deployed to provide a hydrographic depiction of the water column (e.g., cast). The CTD recorded measurements of conductivity, temperature, and pressure at a rate of one sample every 0.5 second as it was lowered through the water column. The internal data logger stored data records for individual casts until the data were transferred (downloaded) to a laptop computer. Data dumps (downloads) were performed in duplicate at the completion of each field sampling day. One data set was sent to the URS office in Anchorage. All data acquisition activities were conducted in accordance with, and did not vary from, the standard operating procedures provided in the Work Plan (URS Greiner Woodward Clyde 2000).

To collect sufficient water column temperature and salinity data, two hydrography surveys were conducted. The nearshore survey collected hydrography data adjacent to the proposed gravel-fill dock structure and the surf-zone survey collected hydrography data immediately adjacent to selected fyke net locations. During the field season, 20 days of temperature and salinity profiles were collected to support the docking structure baseline and surf-zone (fyke net) surveys (Figure 3.1). Typically, the surveys were conducted at 2- to 3-day intervals during July and August 1999. However, 7 consecutive days of high winds and waves prevented the field party from collecting hydrography data in mid- to late August.

<u>Nearshore Surveys</u>: A network of 27 hydrography sampling stations were established along five north-south oriented transects (Figure 3.2). Transect lengths were 6,000 ft (1,800 meters) or 3 times the proposed length of the gravel-filled dock, with a maximum transect length being the lagoon width. One transect (Transect 99C) coincided with the proposed dock location, with two sets of transects located on either side. Transect spacing was approximately 2,000 to 6,000 ft (600 to 1,800 meters) or about 1 to 3 times the proposed length of the gravel-fill dock. Where practical, several of the 1999 sample stations were established at 1998 station locations.

<u>Surf-Zone Surveys</u>: The regulatory community raised concerns that the immediate nearshore, or surf-zone hydrography (i.e., temperature and salinity) has not been adequately described in past studies. Thus, surf-zone transects were established at selected fyke net sites located within Lions Lagoon, with transects extending from the fyke net, seaward approximately 330 ft (100 meters).

Sample stations were positioned at 25-meter intervals (i.e., fyke net, 25-m, 50-m, 75-m, and 100-m stations).

3.3 METEOROLOGY

A Weatherpak® 2000 portable meteorological station was deployed east of Point Thomson on the mainland shore south of the west tip of Flaxman Island (Figure 3.2). The unit is a stand-alone automatic meteorological station mounted on a tripod and secured with sandbags attached to each leg of the 3-meter tripod for stability. The site was selected to provide representative site-specific meteorological data for use in understanding site-specific physical oceanography and fisheries studies. The meteorological station measured wind velocity (e.g., speed and direction), air temperature, and barometric pressure. The meteorology station was deployed in early July; however, software communications and power interruptions resulted in no data collection until July 14, 1999. Throughout the remainder of the study (July 15, 1999 to August 26, 1999), the meteorology station recorded continuous measurements in 10-minute intervals without further loss of data.

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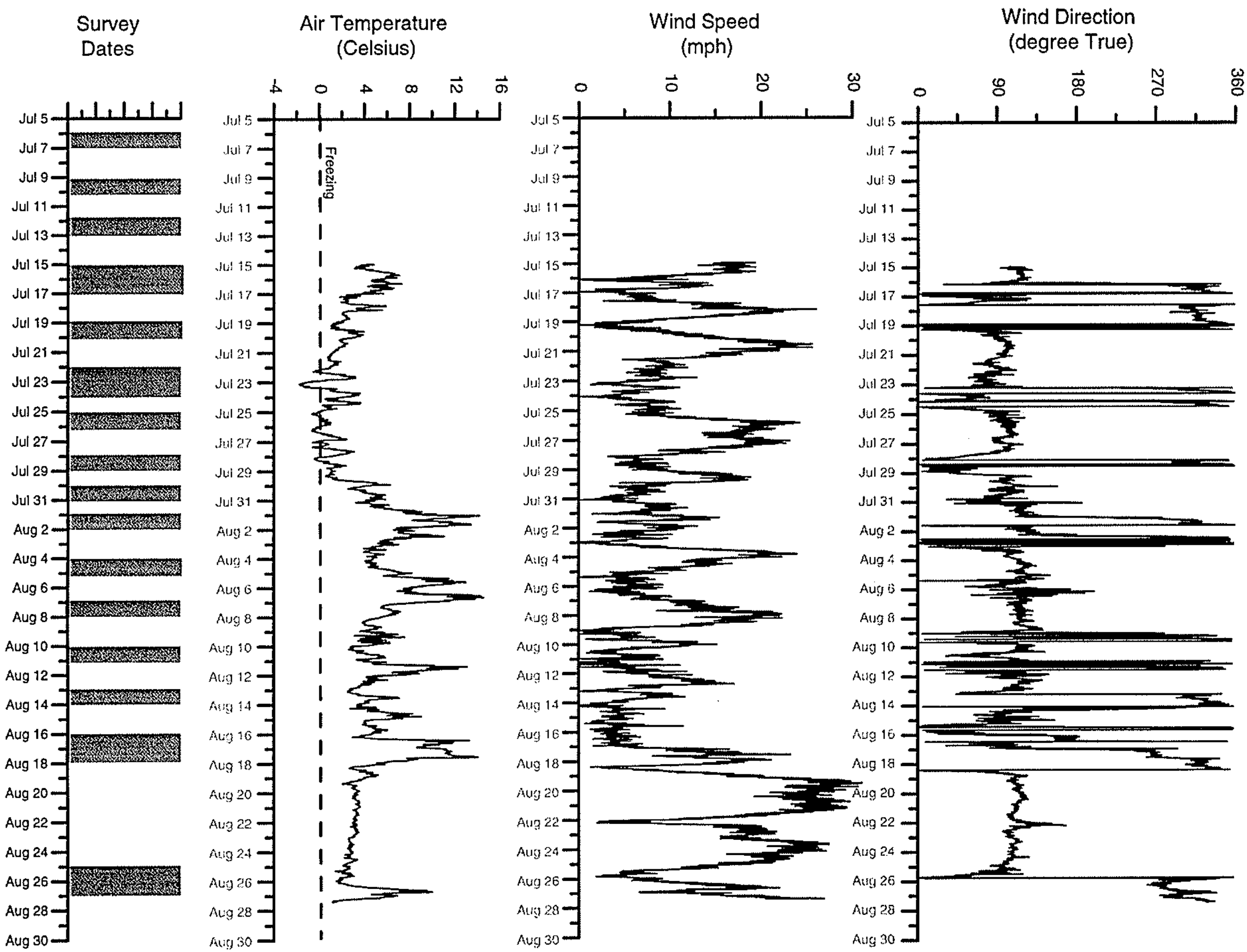

Figure 3.1 1999 Summer Meteorology Record at Point Thomson

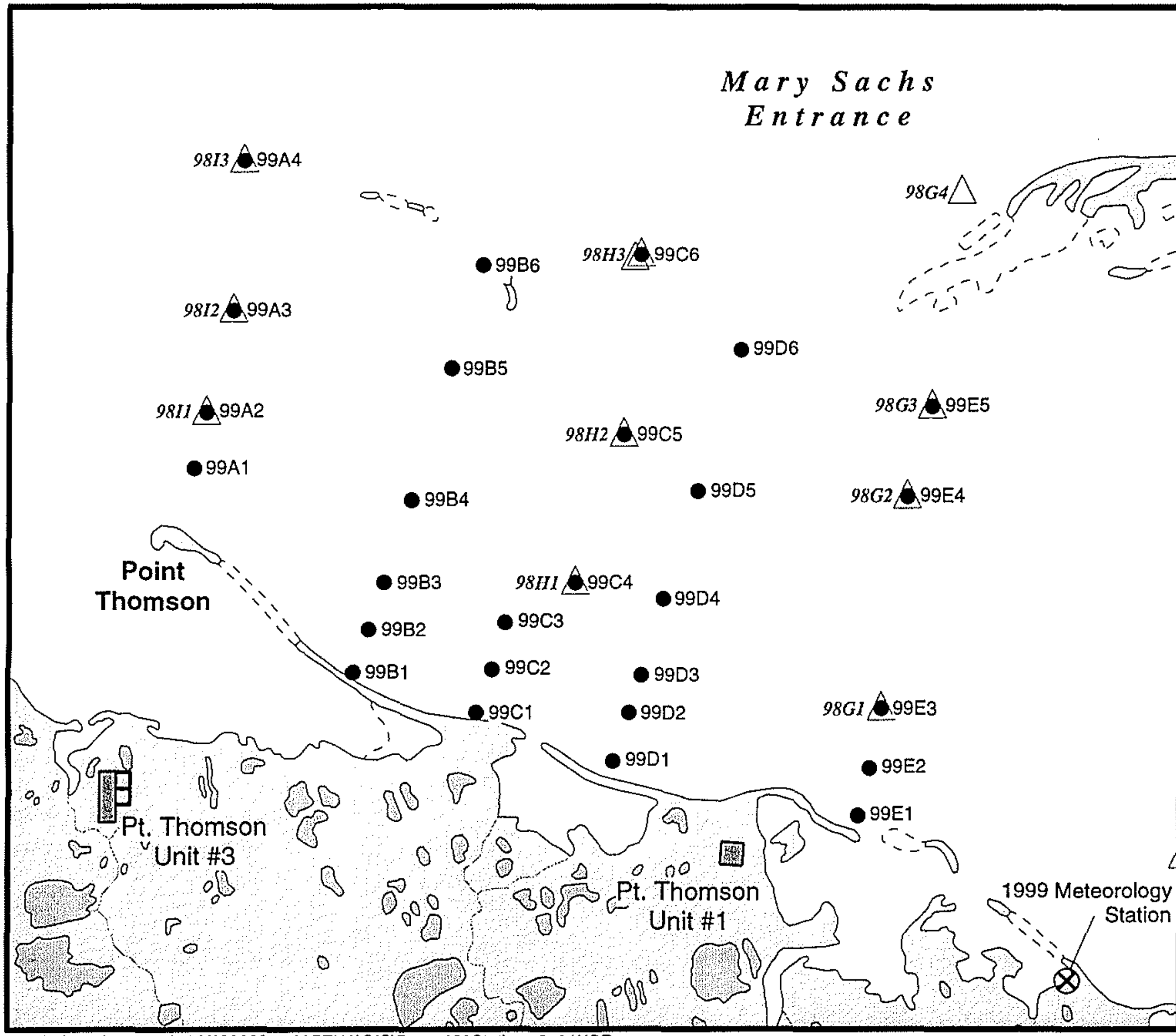

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FIGURE 3.2

1999 Physical Oceanography

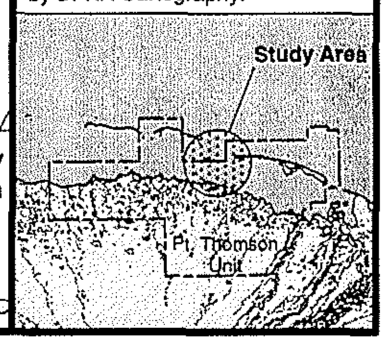
Docking Structure CTD Stations and Meteorology Station

NORTH

0 0.25 0.5
statute miles

Legend:
△ 1998 CTD Station
● 1999 CTD Station

Notes:
Base map was digitized from USGS 1:63360 Topographic Map by BPXA Cartography.



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4.1 METEOROLOGY

Easterly winds, winds out of the east, were prevalent throughout the 1999 summer open-water season. The meteorology station located east of Point Thomson recorded approximately 31 days of east winds during its 43-day continuous data set (Figure 4.1). Similar records were recorded at the West Dock Meteorology and Tide Level Station maintained by NOAA (Figure 4.1).

Typically, easterly winds persisted for 2- to 5-consecutive day periods, and separated by 1- to 3-day intervals of westerly or mixed easterly/westerly winds. A notable exception was the 8-day easterly storm that lashed the coastal Beaufort Sea coast with winds in excess of 30 miles per hour (MPH). Immediately prior to this storm, winds were mixed easterly/westerly for about 6 days. The 50th percentile or median wind speed measured at the meteorology station east of Point Thomson was about 8 MPH, and 90 percent of the winds were less than 20 MPH (Figure 4.2). Wind directions were bimodal with easterly winds accounting for approximately 70 percent of the observations, with the majority of easterly winds between 100° and 120° from true north (Figure 4.3).

Air temperatures recorded east of Point Thomson were typically between freezing and 10°C (50°F) throughout the study. Temperatures dropped below freezing (0°C or 32°F), for a couple of days in late July and rose above 10°C (50°F) only four times in early to mid August 1999.

4.2 WATER COLUMN SALINITY AND TEMPERATURE

Twenty days of water column salinity and temperature profiles were collected throughout July and August 1999. Daily maps and transect cross-sections of salinity and temperature are included in the Appendices following this report.

4.2.1 Docking Structure (Mary Sachs Entrance) Baseline Surveys

The first survey was delayed until July 6, 1999 due to significant concentration of ice floes in Lions Lagoon and Mary Sachs Entrance. Immediately after the initial opening of water within the lagoon, it was observed that sea ice melting resulted in the formation of fresh (<5 parts per thousand [‰]) and uniform surface waters within the study area (Figure 4.4). The freshwater surface layer was approximately 2 meters thick and covered 22‰ bottom water (Fig 4.5).

Discharge from the Staines River was encountered in numerous surveys with significant input observed between July 13 and July 30, 1999. Typically, this freshwater input was restricted to the surface and moved toward the west during easterly winds. As the freshwater (<10‰) plume moved into Mary Sachs Entrance on July 15, mixing occurred with the offshore (~25‰) waters entering from the north (Figure 4.6). The result of mixing was an increase in surface water salinity observed west of Mary Sach Entrance. Also, mixing served to thin the surface freshwater plume. Transect 99E, situated east of Mary Sachs Entrance and protected by Flaxman Island encountered a 2 meter thick surface plume of fresh (<10‰) water that covered the whole lagoon (Figure 4.7). However, the width and thickness of the plume, as defined by the 10‰ contour, progressively decreased toward the west, with the westernmost Transect 99A encountering a relatively small lens of fresh (<10‰) water.

After a period of westerly winds, the waters within the study area were uniformly brackish (16-20‰) during the July 19 survey, with the exception of a thin ribbon of relatively fresh (<15‰) surface waters associated with Staines River discharge (Figures 4.8 and 4.9). The July 25 survey was conducted a few days later under east winds and substantial amounts of Staines River (<5‰) discharge were found in the study area (Figure 4.10). The easterly winds also drew offshore marine (>30‰) bottom waters into Mary Sachs Entrance. Thus, Transect 99B encountered three distinct water bodies: the surface (<6‰) plume related to the Staines River discharge; brackish (14-28‰) nearshore waters; and, upwelled marine (>30‰) waters found at the north end of the transect (Figure 4.11).

As easterly winds persisted throughout early August, marine (>30‰) waters poured into the lagoon through Mary Sachs Entrance. By August 10, the waters within the study area were uniform and marine (>30‰) (Figure 4.12). The survey area maintained almost uniformly marine conditions throughout the remainder of August, with 29 to 30‰ waters encountered on the last survey (Figures 4.13 and 4.14). While the surface salinities exhibited a slight increase (~1‰) at the west end of the study area, very little to no fresh water associated with the Staines River was encountered after mid-August.

4.2.2 Surf Zone (Fyke Net) Surveys

Sea ice inhibited the setup of fyke nets along the mainland shore surrounding Point Thomson, and only one surf zone transect was surveyed by July 9. By July 15, 1999, all of the fyke nets were deployed, and CTD profiles were collected along the four surf zone transects on the same days as the docking structure surveys.

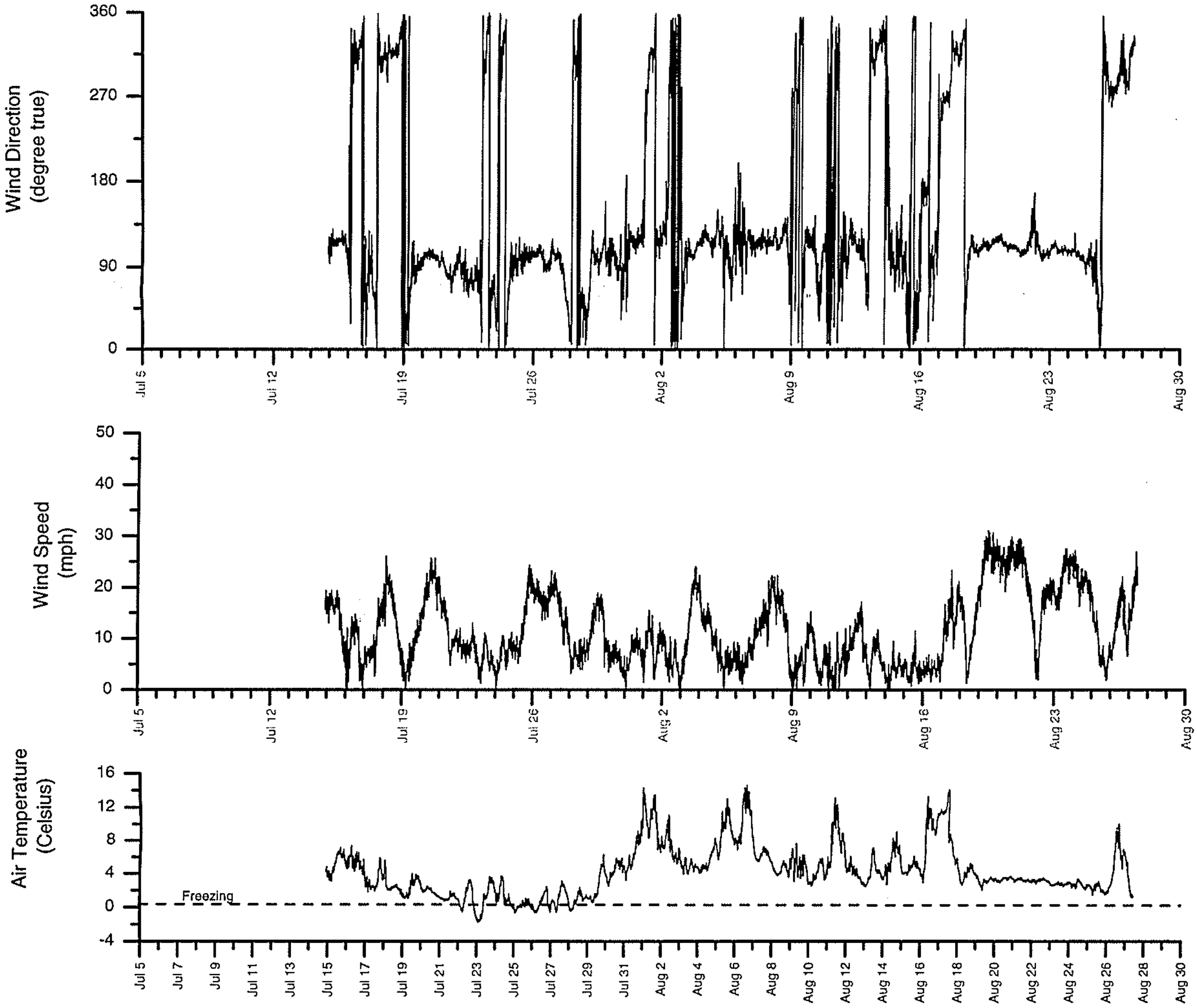
Fresh (<5‰) and uniform waters were found during the July 9 and July 12 surveys as fyke nets were established. Uniform brackish (24-25‰) waters were found west of Point Thomson, while uniform fresh (<5‰) waters surrounded the fyke nets east of Mary Sachs Entrance during the July 15 survey (Figure 4.15). Uniform brackish (12-14 and 18-19‰) waters were found at the western fyke net transects, and uniform relatively fresh (<7‰), waters were found at the eastern fyke net transects on July 16 (Figure 4.16). Net 603 located immediately east of Mary Sachs Entrance and south of the west tip of Flaxman Island was situated at the interface between these two distinct waters. Here, the water column was stratified with a 0.25-meter surface layer of fresh (<7‰) water covering the denser brackish (12-19‰) waters. Similar water column structures occasionally were found during other surveys when the plume associated with Staines River discharge was very thin, usually less than 1 meter, and typically restricted to the east side of Mary Sachs Entrance.

Brackish (>12‰) conditions typify waters found west of Mary Sachs Entrance between July 15 and July 22. The July 23, 1999 survey encountered significant amounts of fresh water, such that the water column was uniform with salinities <4‰ east of Mary Sachs Entrance (Figure 4.17). The fresh water thinned and increased in salinity (8 to 10‰) toward the west, with brackish (14‰) bottom waters observed at the westernmost net (No. 601).

The only other structure observed in the surf zone water column during the study was an upwelling feature at Net 603 on July 28, 1999 (Figure 4.18). Otherwise, the waters surrounding the fyke nets and along the surf zone transects were uniform, with periodic pulses of Staines River water forming stratified conditions. By August 7, 1999, all of the fyke net transects found uniform brackish (23 to 29‰) waters (Figure 4.19), and these conditions persisted for the remainder of the study.

Figure 4.1 1999 Summer Meteorology Data

Point Thomson



NOAA Station #9497645 1, Prudhoe Bay, Alaska

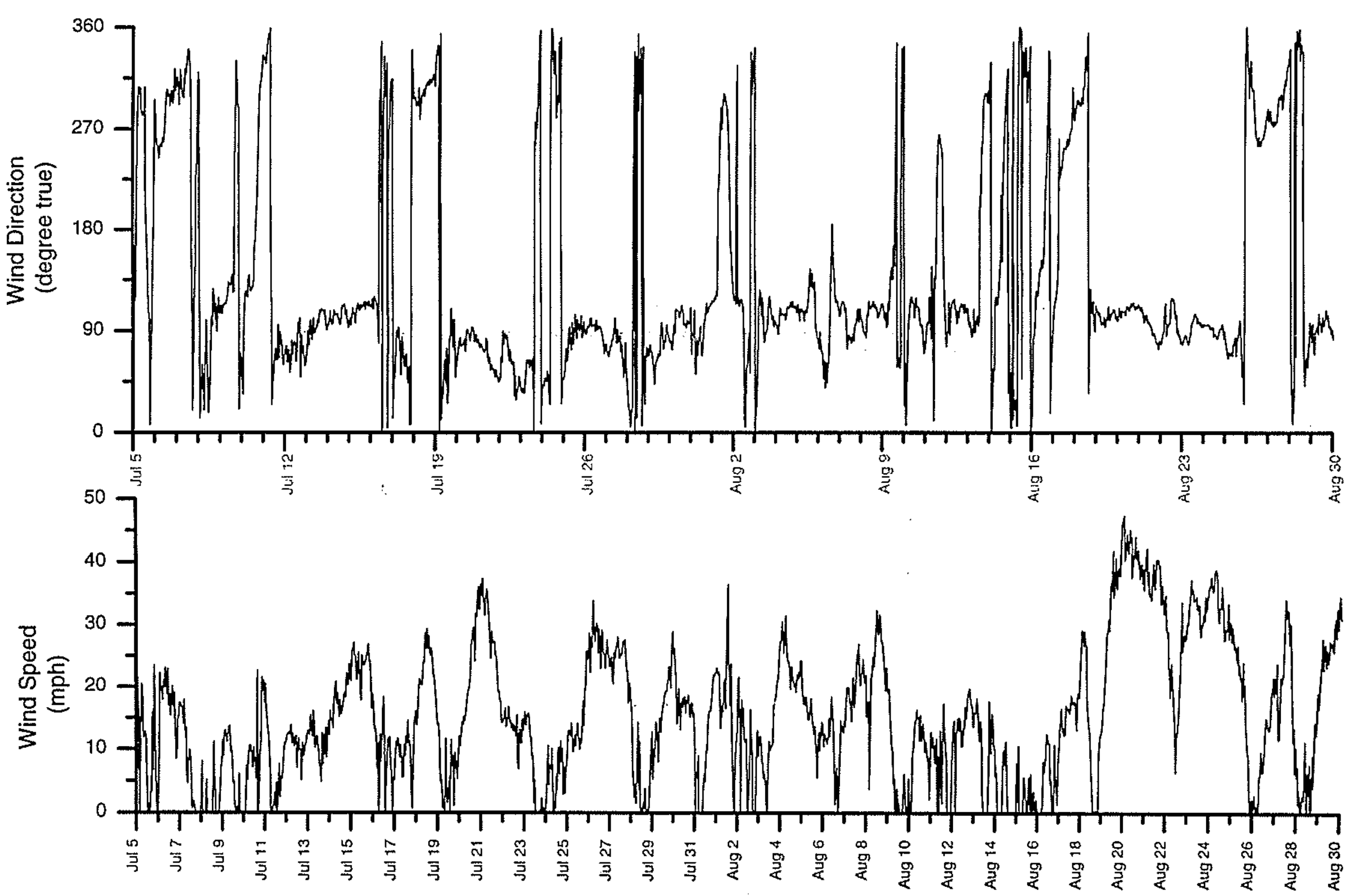


Figure 4.2 1999 Wind Speed Distribution - Point Thomson, Alaska

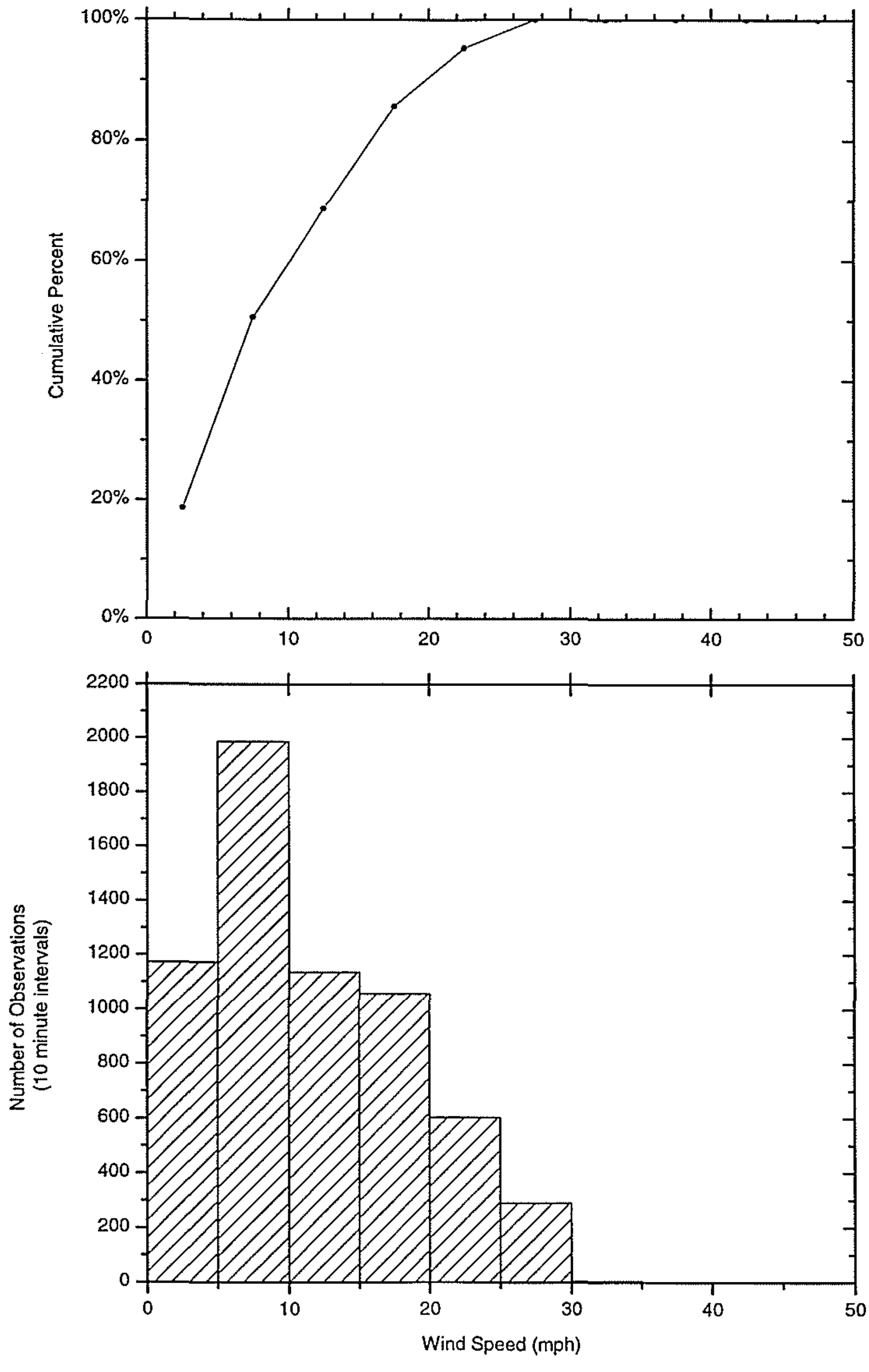


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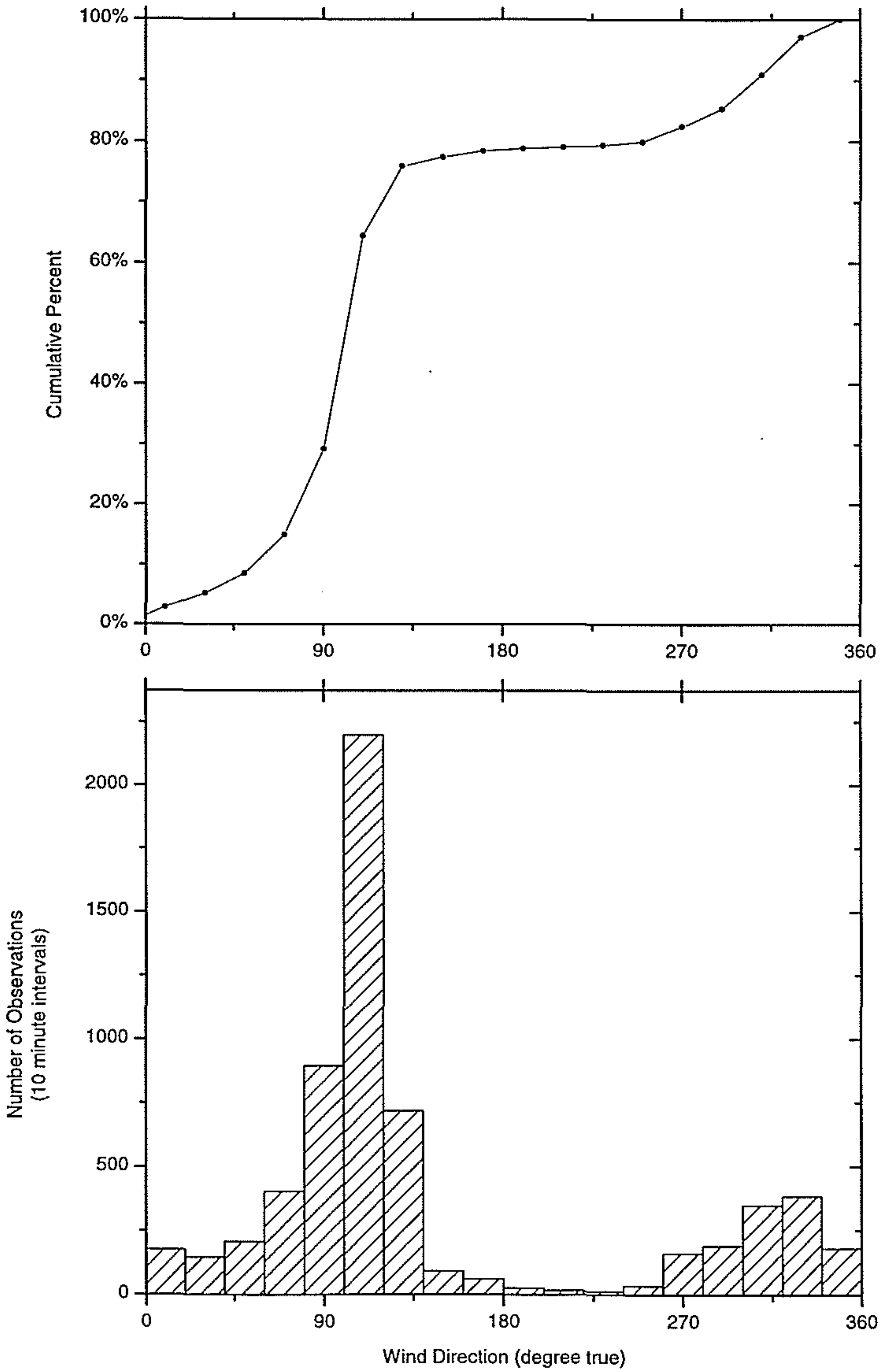
Figure 4.3 1999 Wind Direction Distribution - Point Thomson, Alaska



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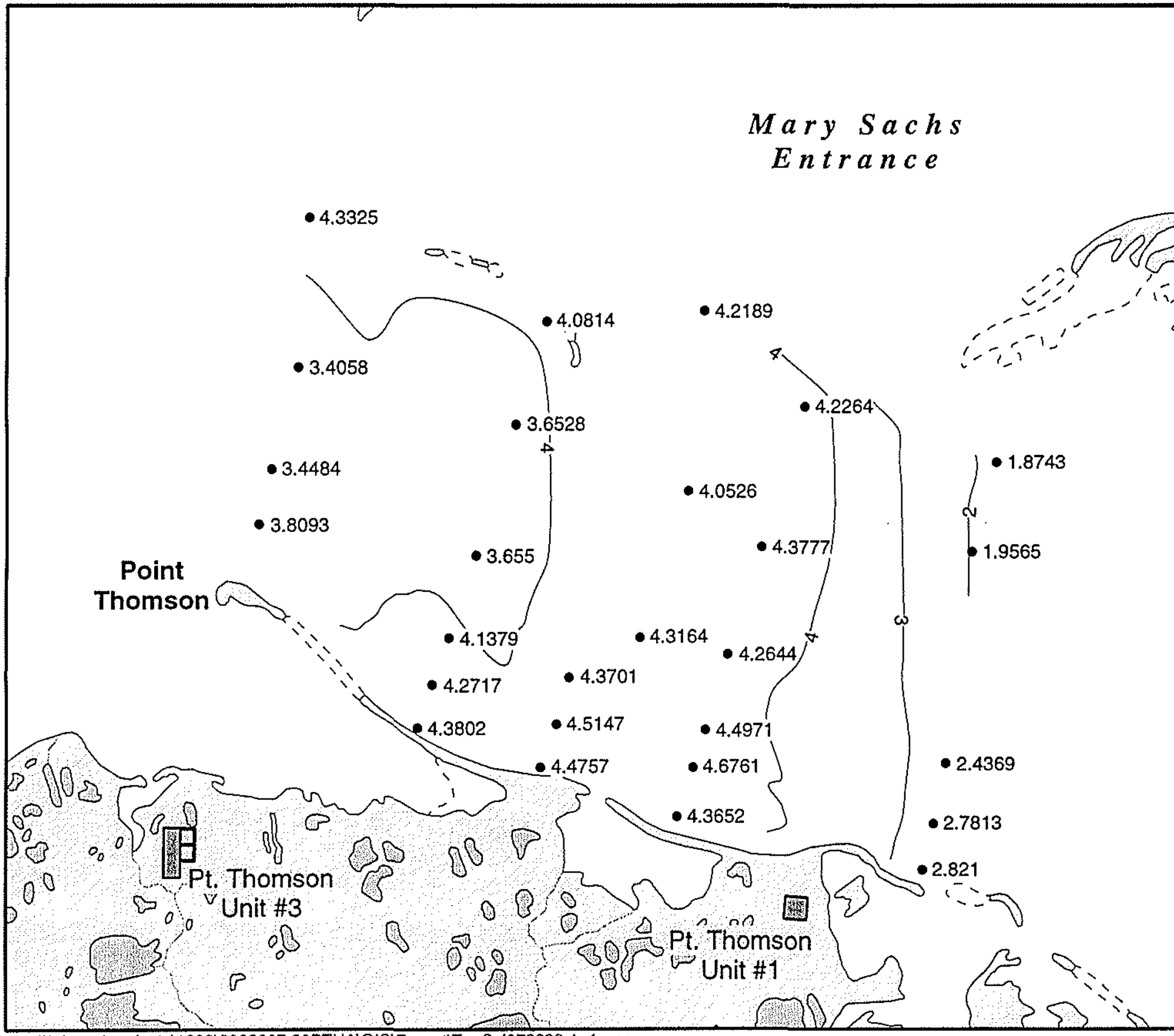

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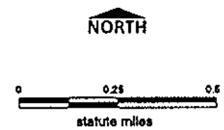
FIGURE 4.4

1999 Physical Oceanography

July 6, 1999
Surface Salinity
(parts per thousand)



Notes:
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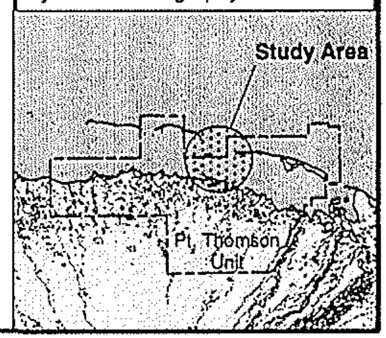

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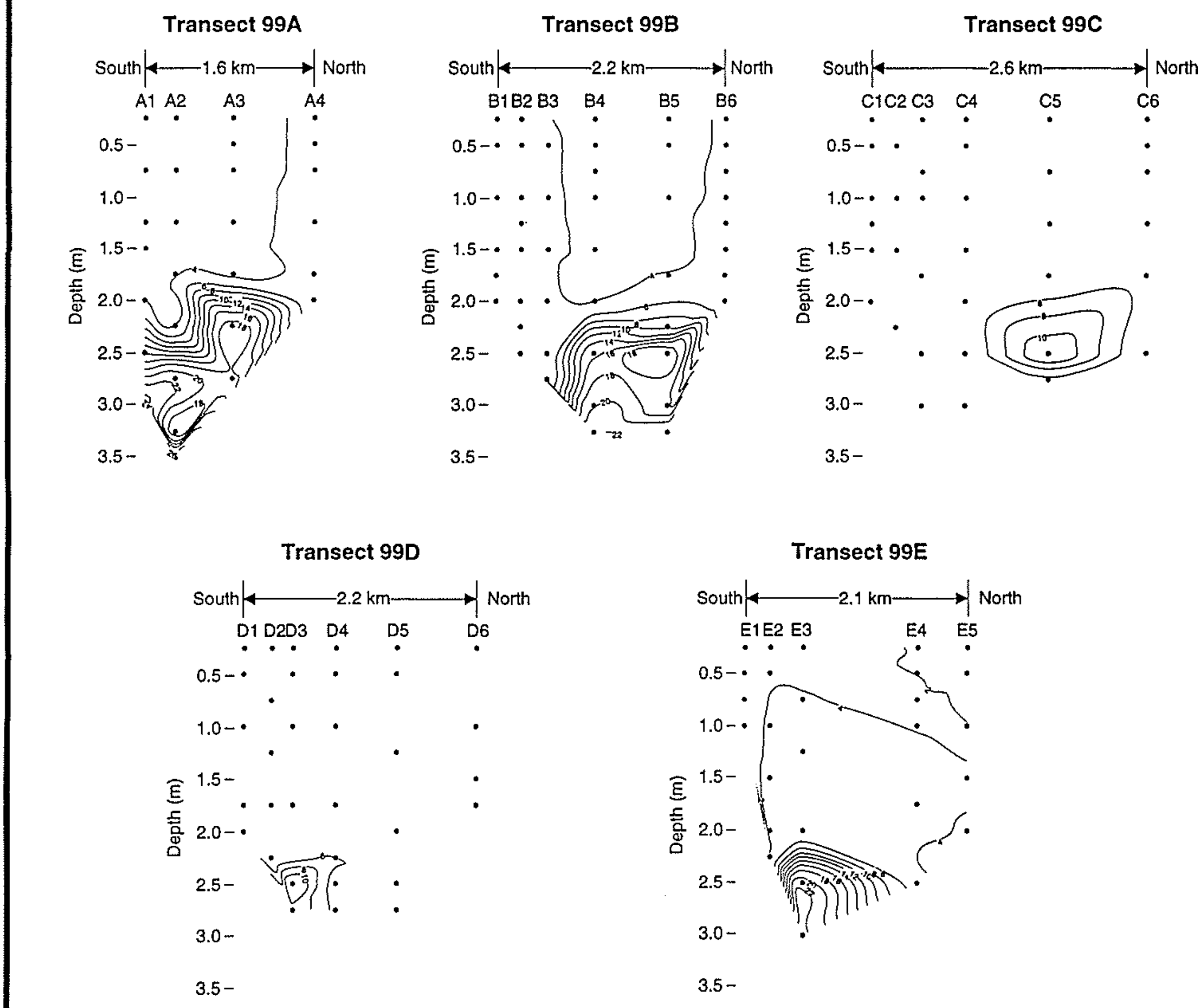

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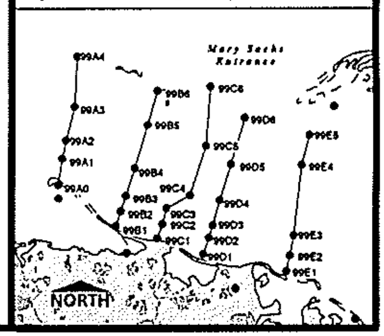
FIGURE 4.5

1999 Physical Oceanography

July 6, 1999 Salinity Transects (parts per thousand)

Notes:
Base map was digitized from USGS 1:63360 Topographic Map by BPXA Cartography.



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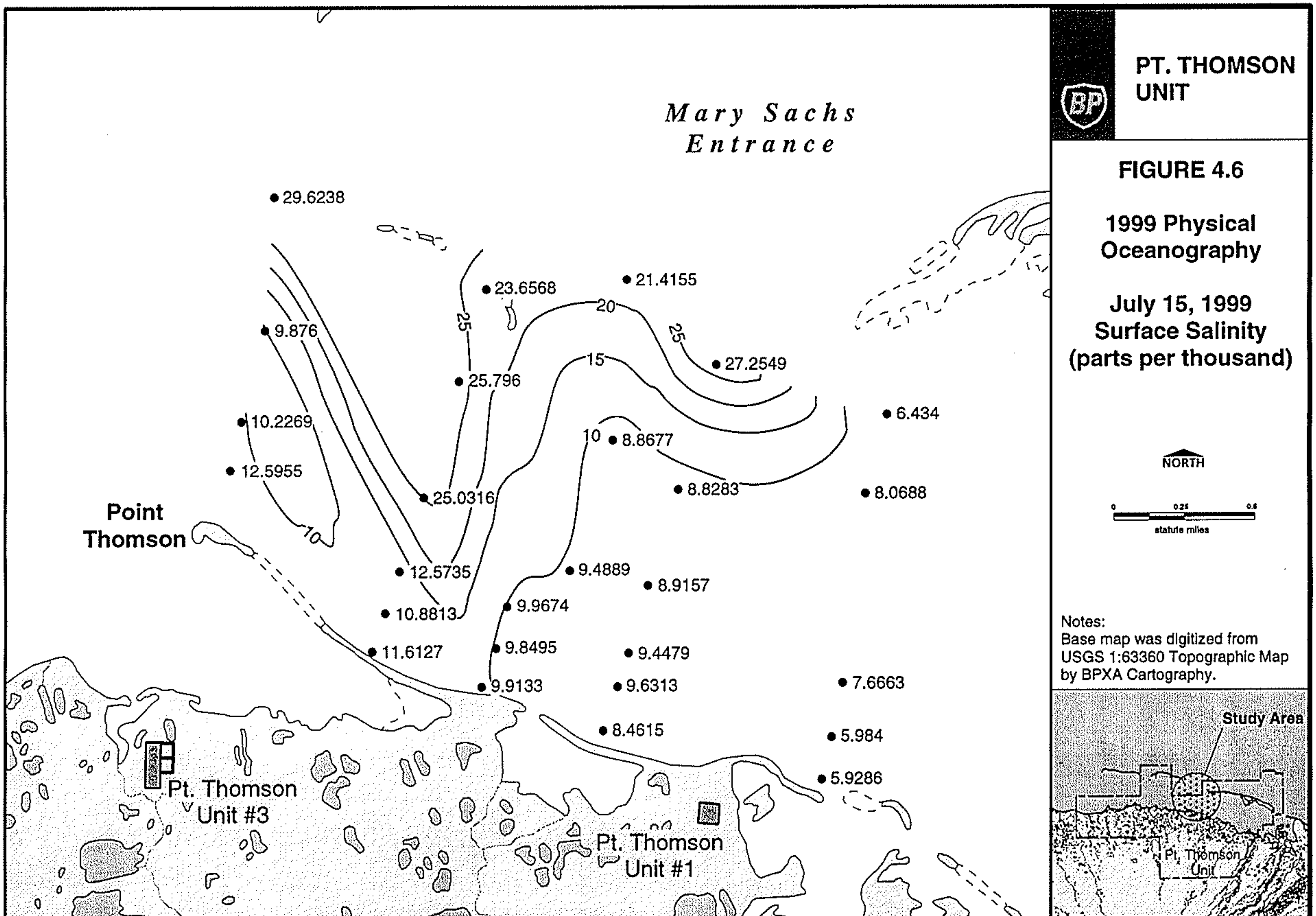

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FIGURE 4.6

1999 Physical Oceanography

July 15, 1999 Surface Salinity (parts per thousand)

Notes:
Base map was digitized from USGS 1:63360 Topographic Map by BPXA Cartography.

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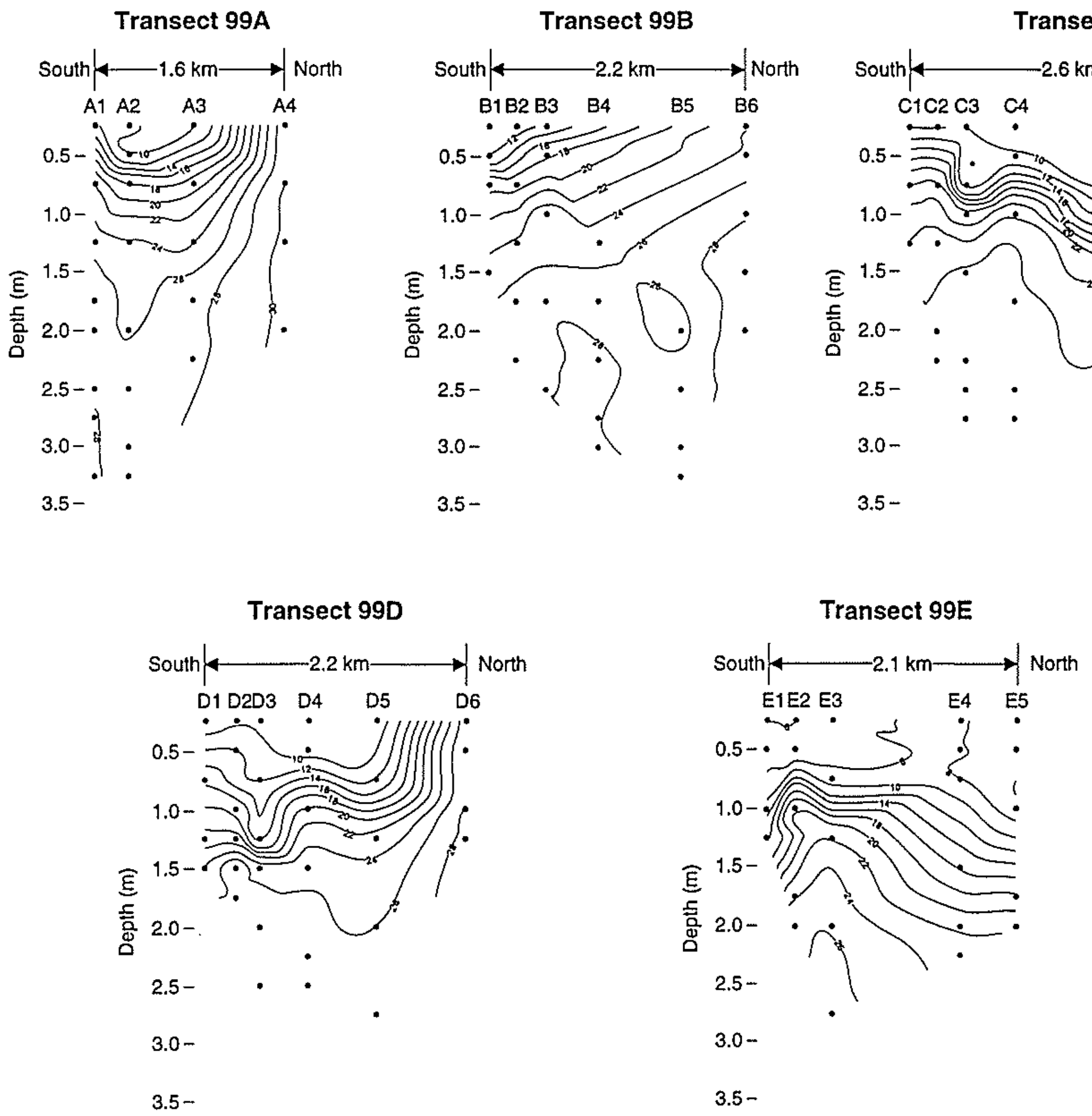

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FIGURE 4.7

1999 Physical Oceanography

July 15, 1999 Salinity Transects (parts per thousand)

Notes:
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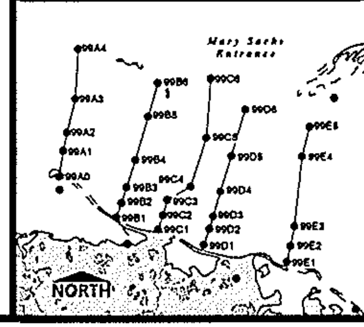

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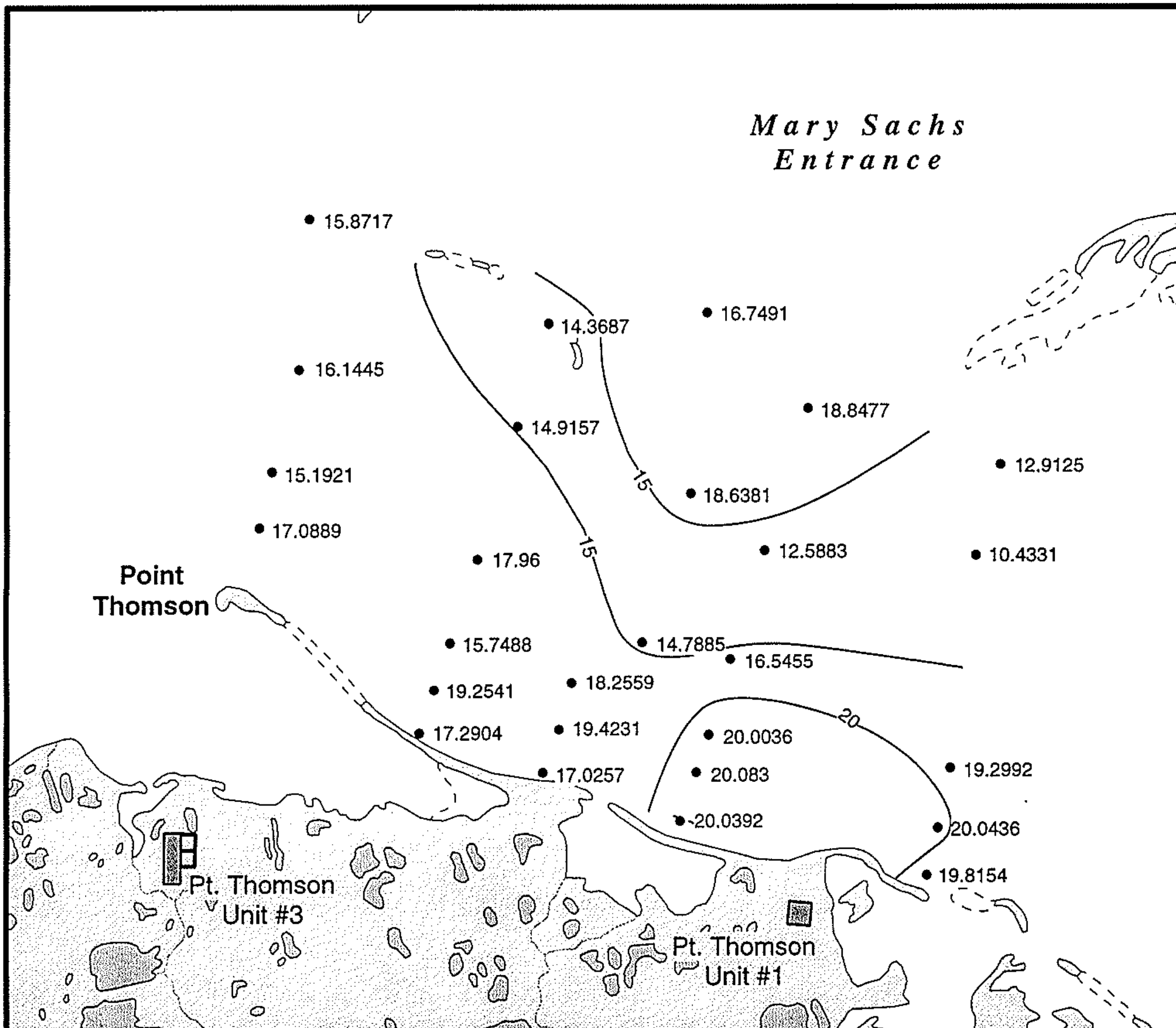

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FIGURE 4.8

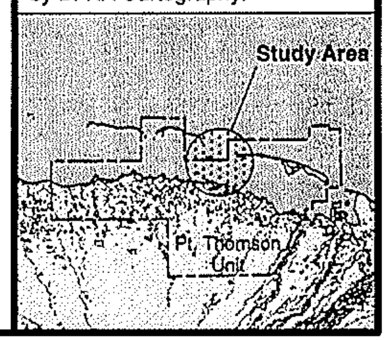
1999 Physical Oceanography

July 19, 1999 Surface Salinity (parts per thousand)

NORTH

0 0.25 0.5
statute miles

Notes:
Base map was digitized from USGS 1:63360 Topographic Map by BPXA Cartography.



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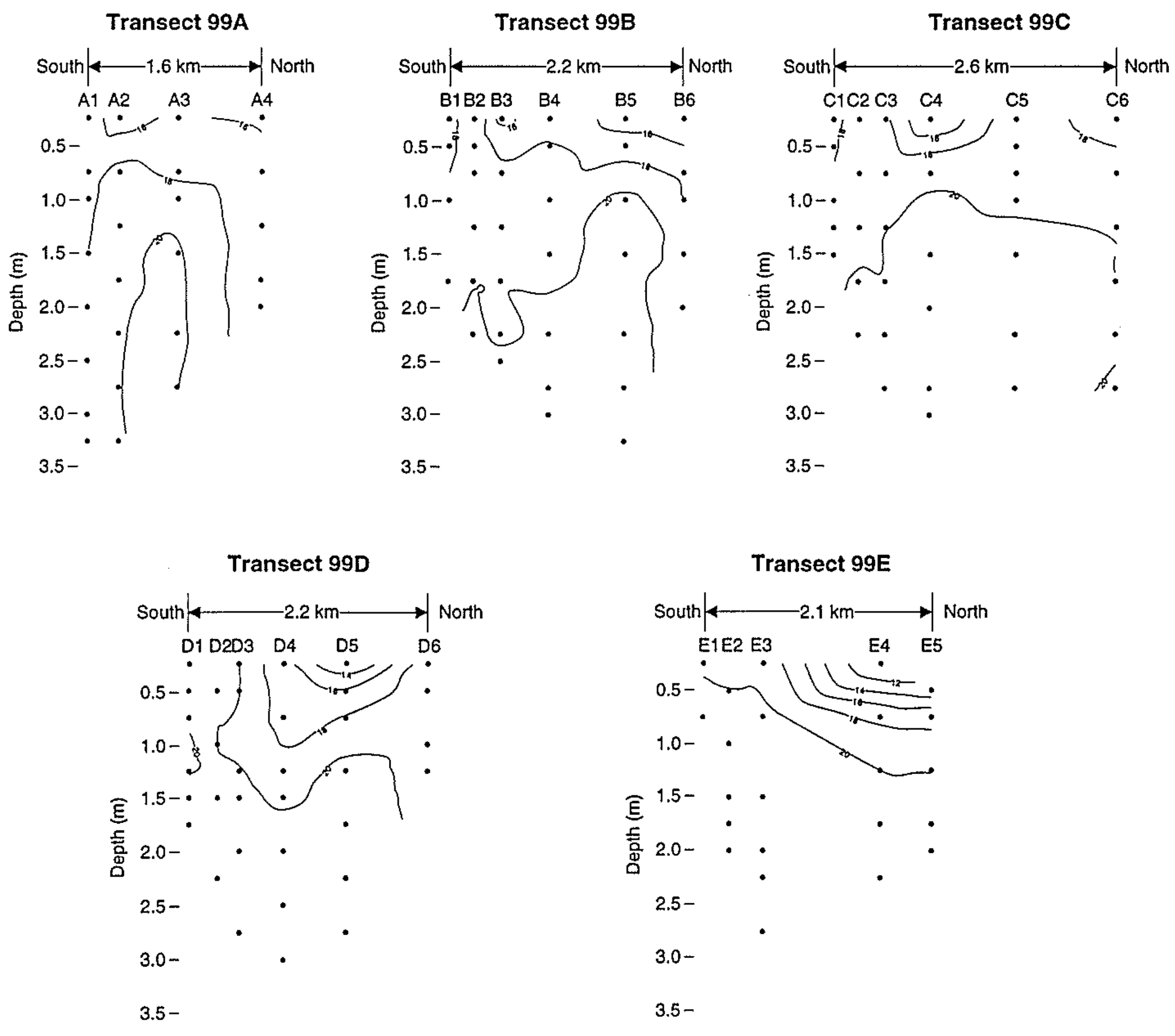

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FIGURE 4.9

1999 Physical Oceanography

July 19, 1999 Salinity Transects (parts per thousand)

Notes:
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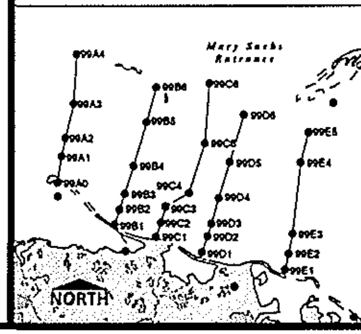

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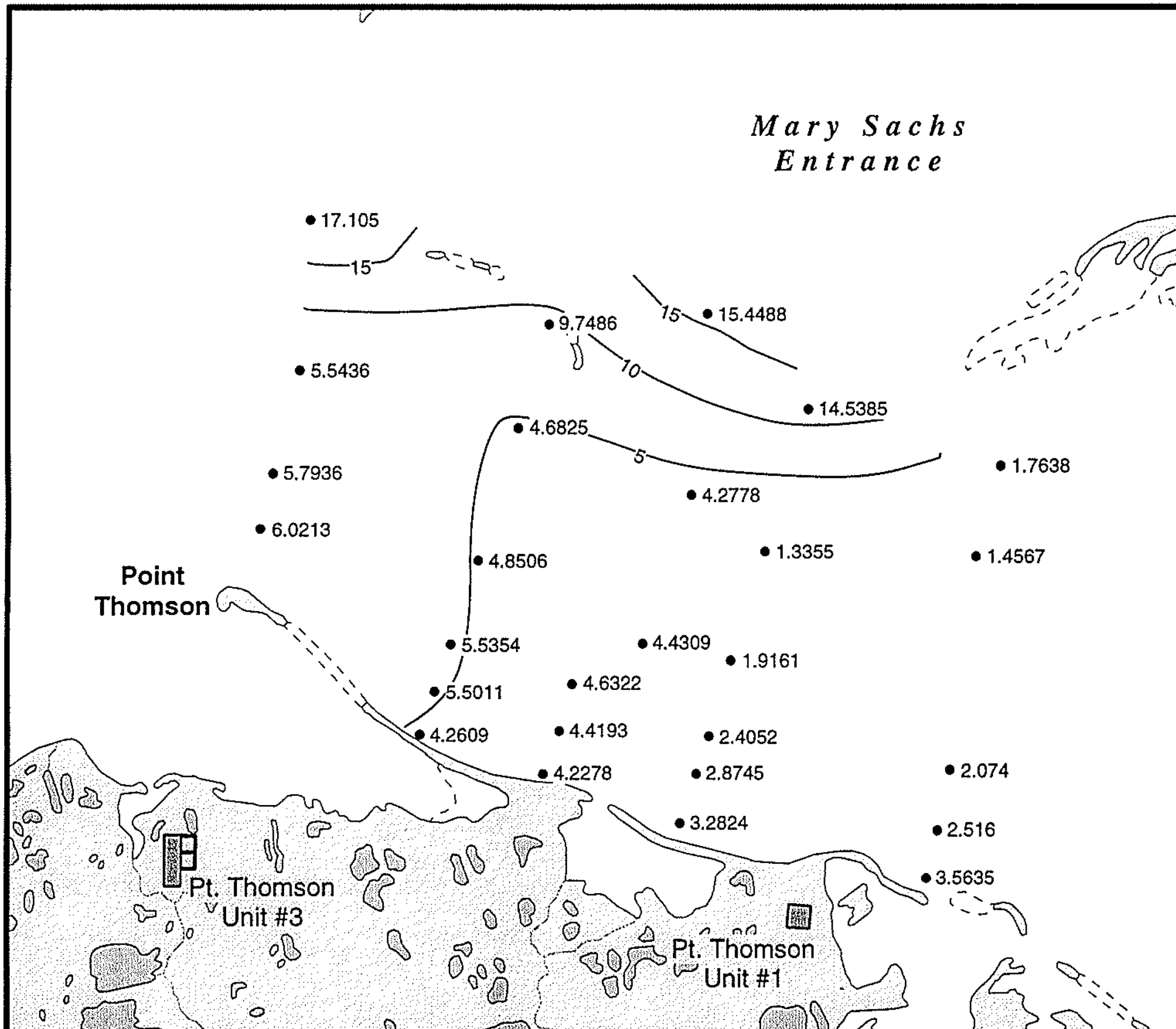

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FIGURE 4.10

1999 Physical Oceanography

July 25, 1999 Surface Salinity (parts per thousand)

Notes:
Base map was digitized from USGS 1:63360 Topographic Map by BPXA Cartography.

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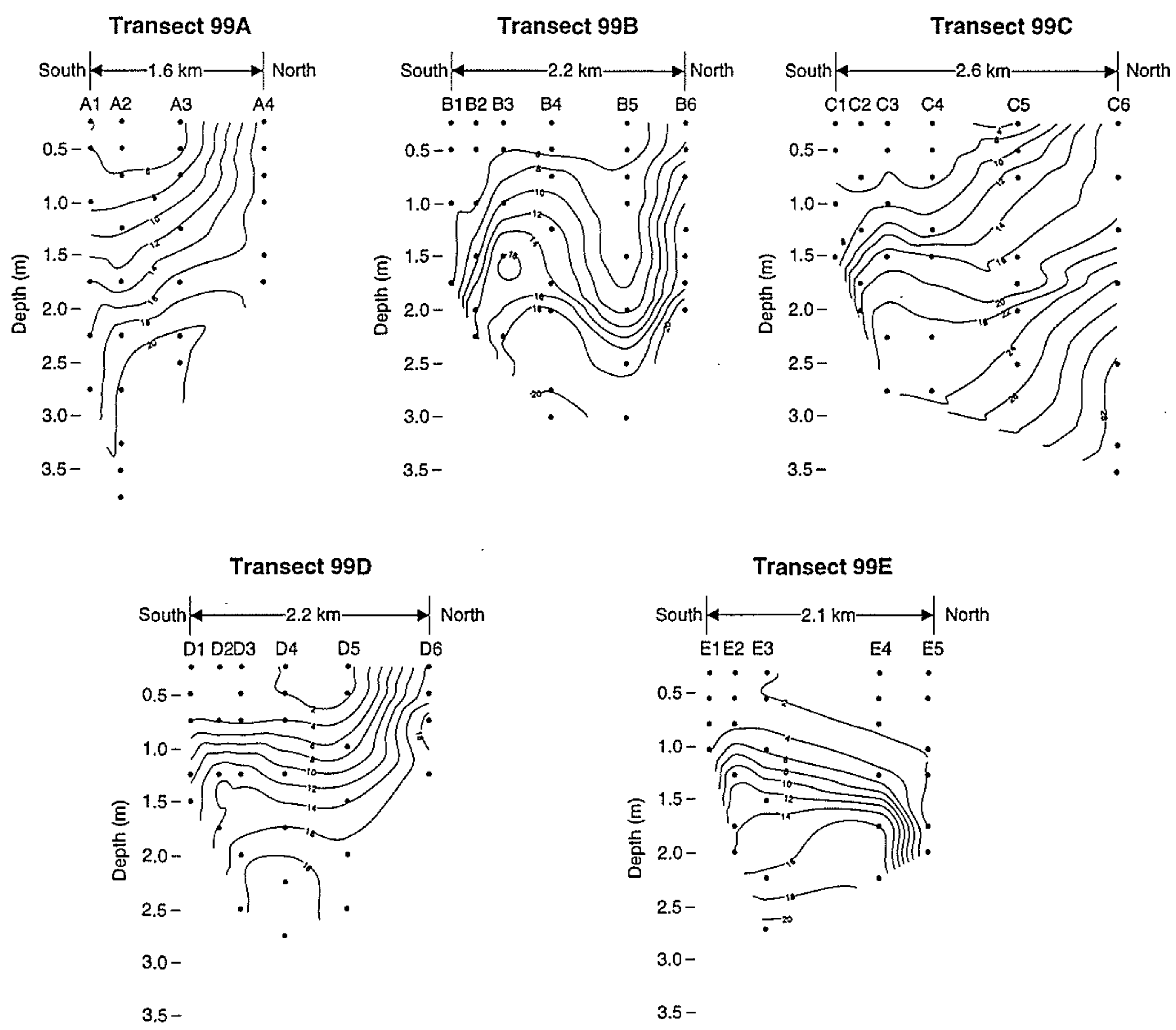

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FIGURE 4.11

1999 Physical Oceanography

July 25, 1999 Salinity Transects (parts per thousand)

Notes:
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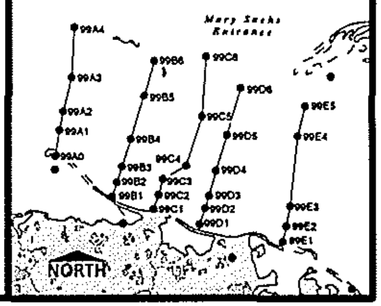

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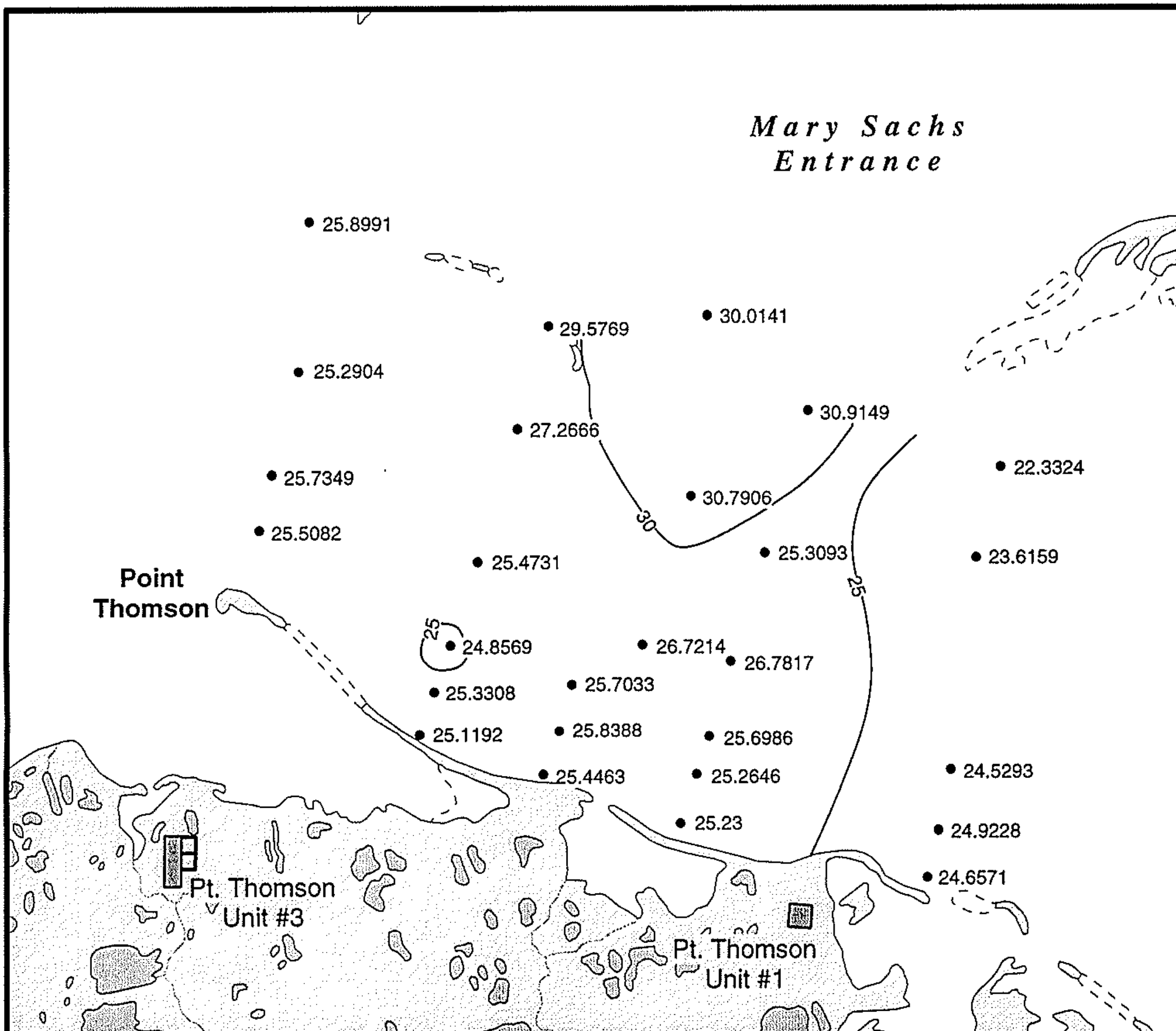


FIGURE 4.12

1999 Physical Oceanography

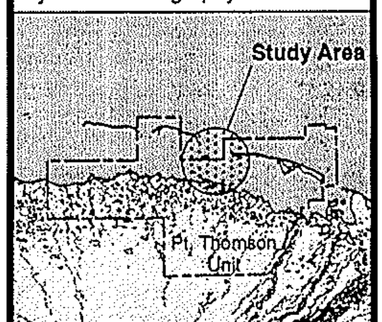
August 10, 1999 Surface Salinity (parts per thousand)

NORTH

0 0.25 0.5

statute miles

Notes:
Base map was digitized from USGS 1:63360 Topographic Map by BPXA Cartography.



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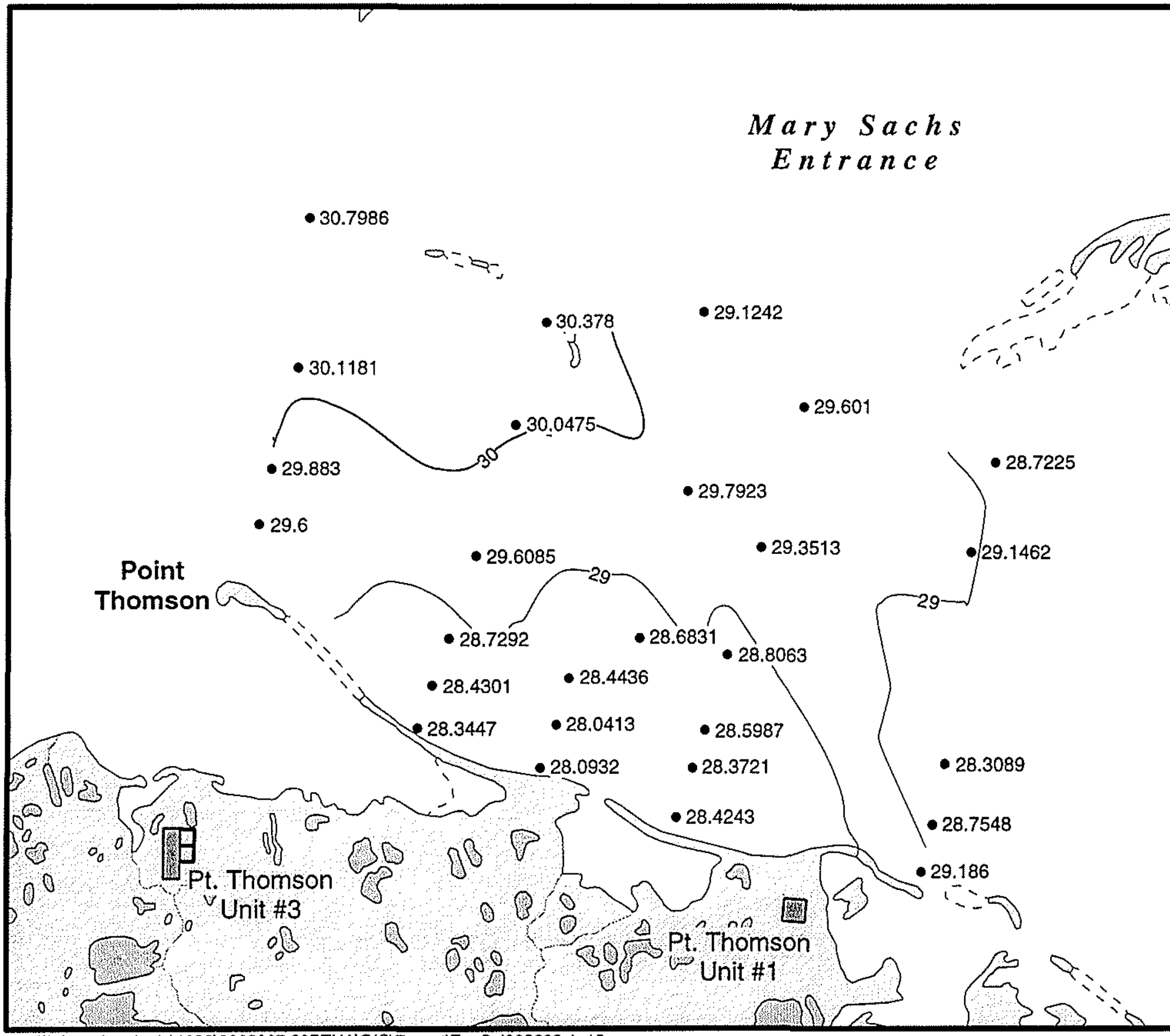

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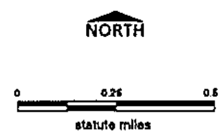
FIGURE 4.13

1999 Physical Oceanography

August 26, 1999 Surface Salinity (parts per thousand)



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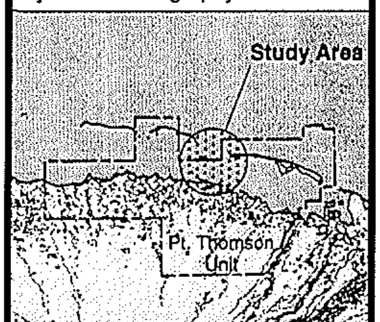

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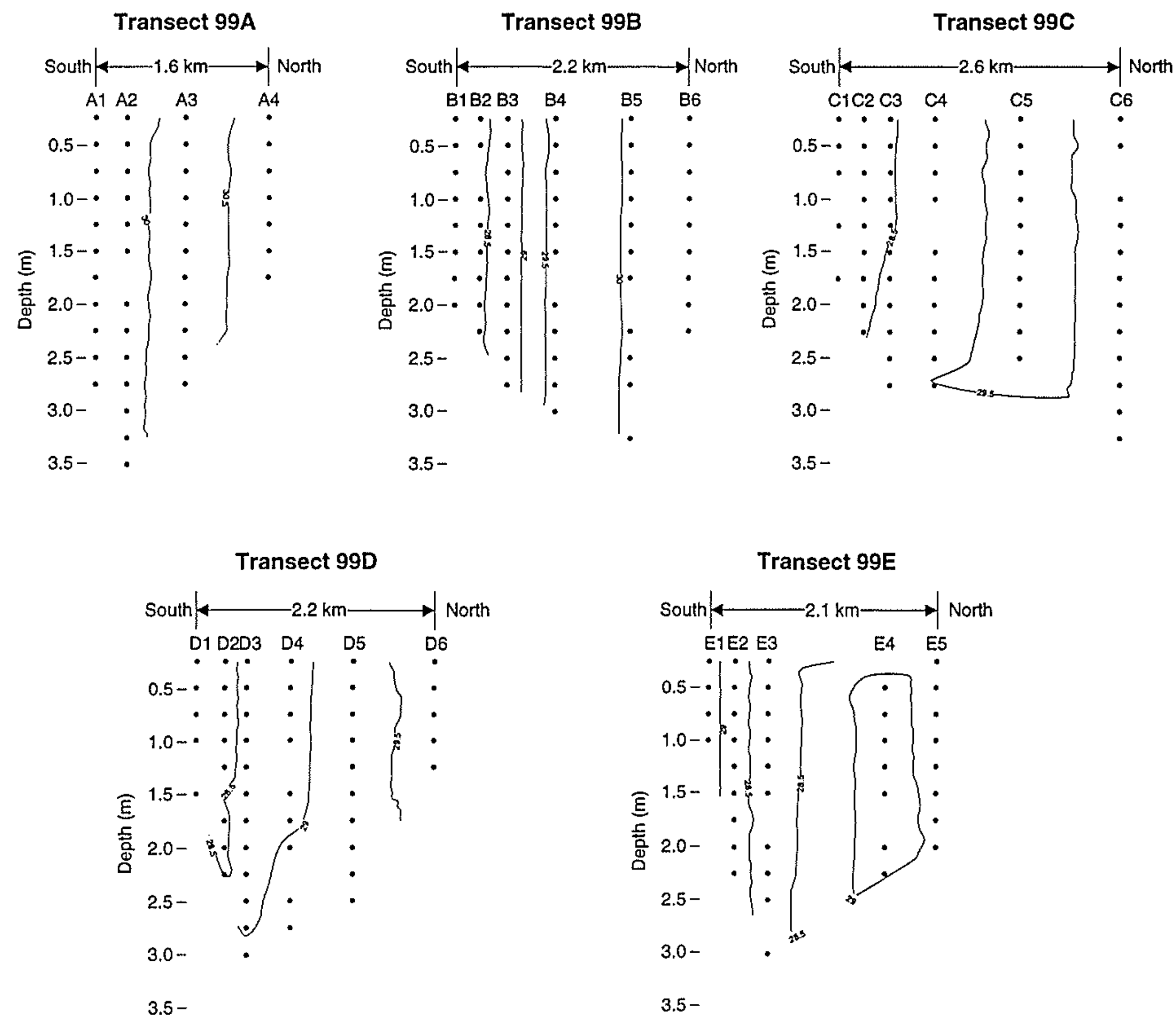

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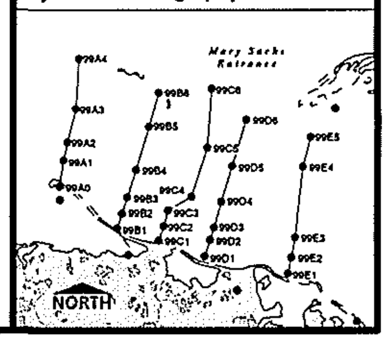
FIGURE 4.14

1999 Physical Oceanography

August 26, 1999 Salinity Transects (parts per thousand)

Notes:
Base map was digitized from USGS 1:63360 Topographic Map by BPXA Cartography.



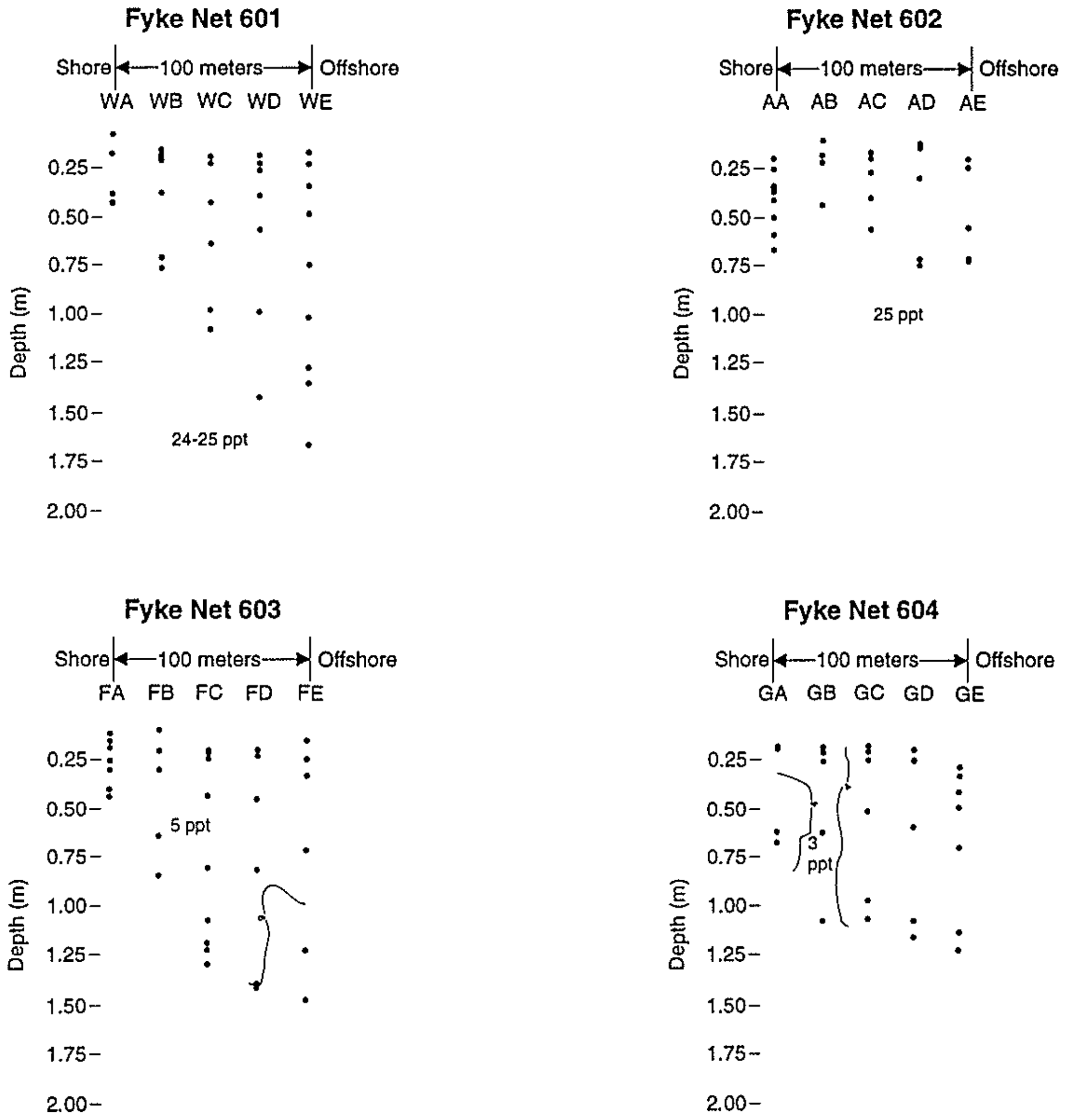


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FIGURE 4.15

1999 Physical Oceanography

July 15, 1999
Salinity
(parts per thousand)
Surf Zone
Transects

Notes:
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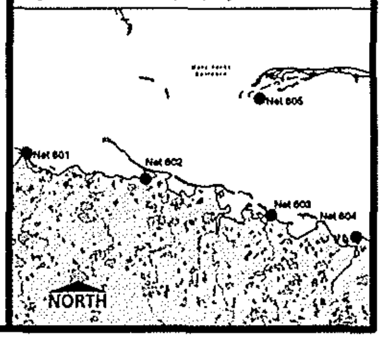

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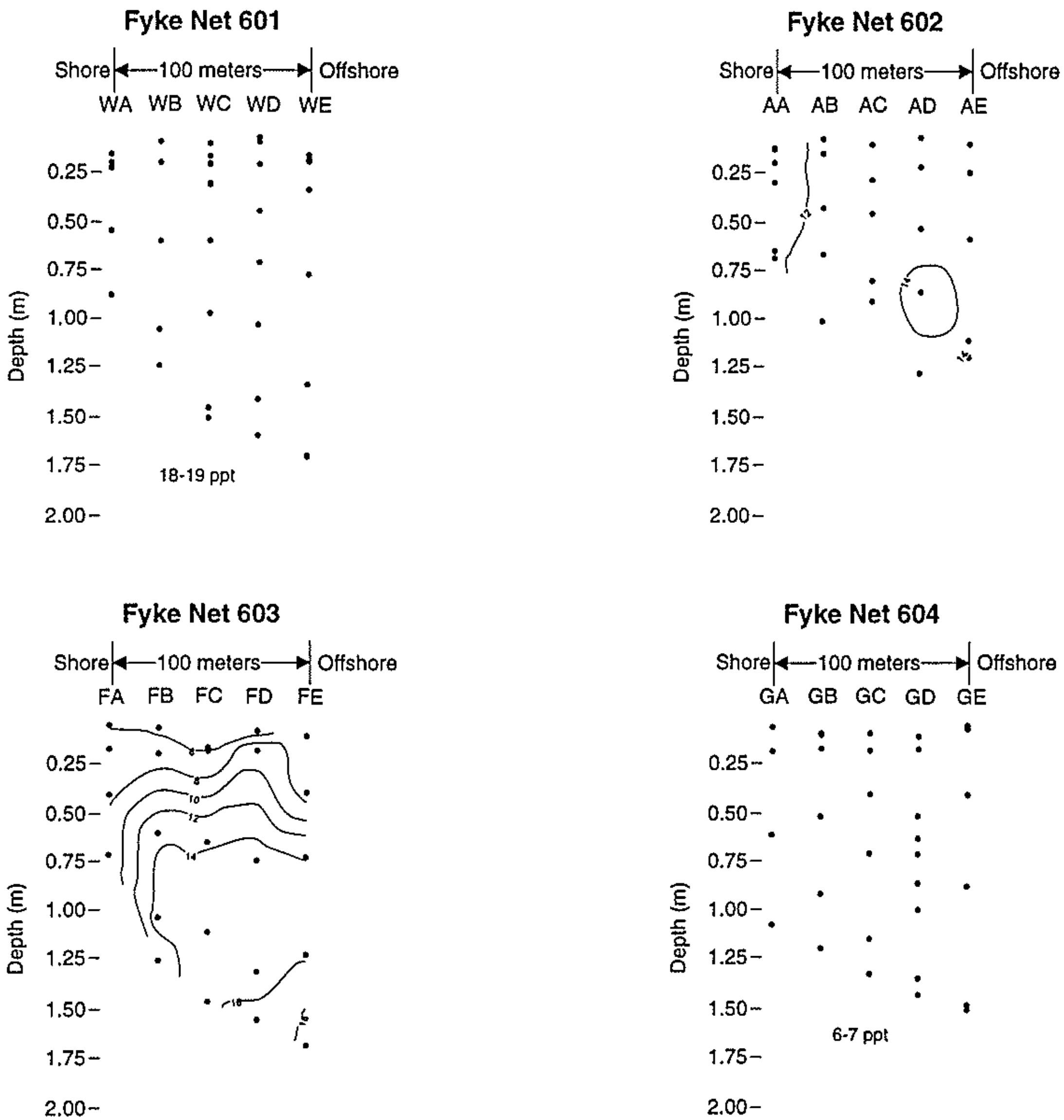

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FIGURE 4.16

1999 Physical Oceanography

July 16, 1999
Salinity
(parts per thousand)
Surf Zone
Transects

Notes:
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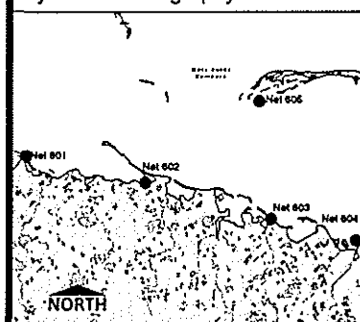

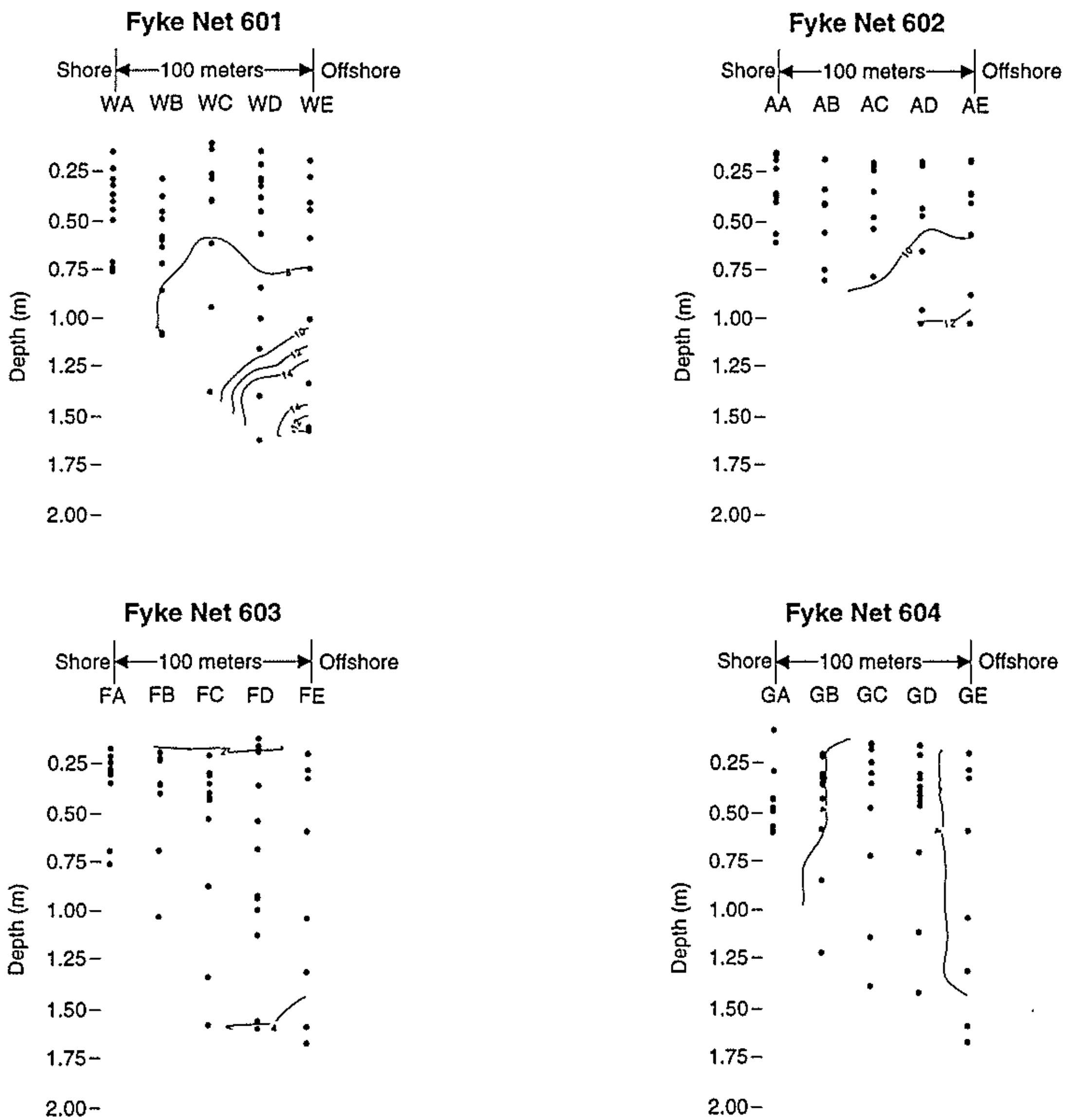

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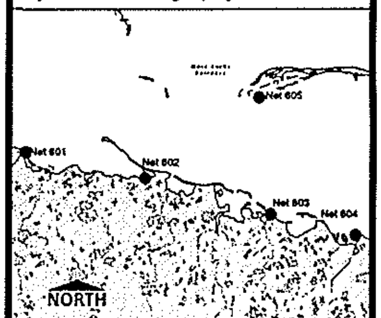
FIGURE 4.17

1999 Physical Oceanography

July 23, 1999
Salinity
(parts per thousand)
Surf Zone
Transects

Notes:
Base map was digitized from USGS 1:63360 Topographic Map by BPXA Cartography.



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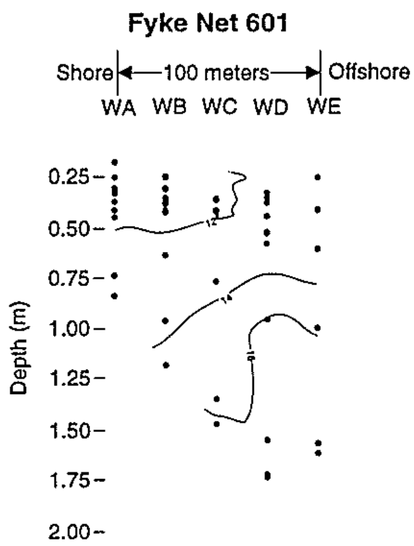

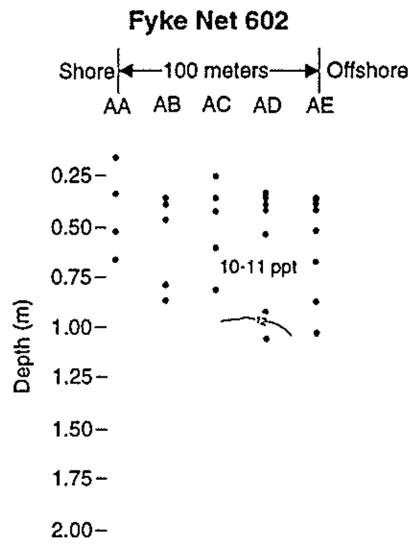

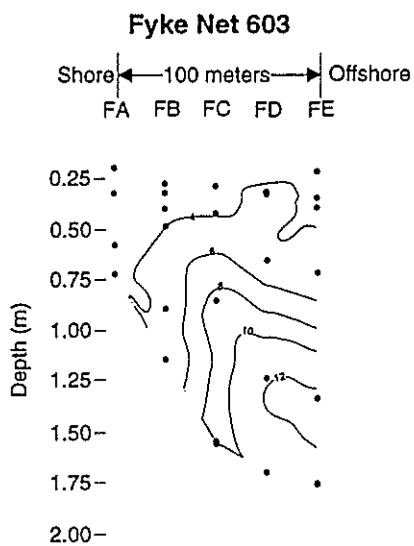

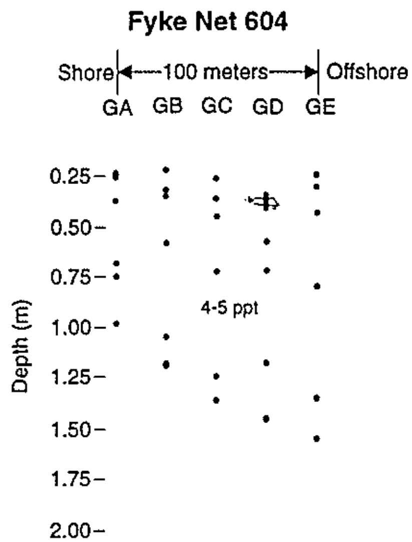

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FIGURE 4.18

1999 Physical Oceanography

July 28, 1999
Salinity
(parts per thousand)
Surf Zone
Transects

Notes:
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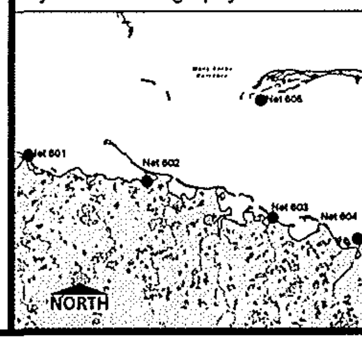

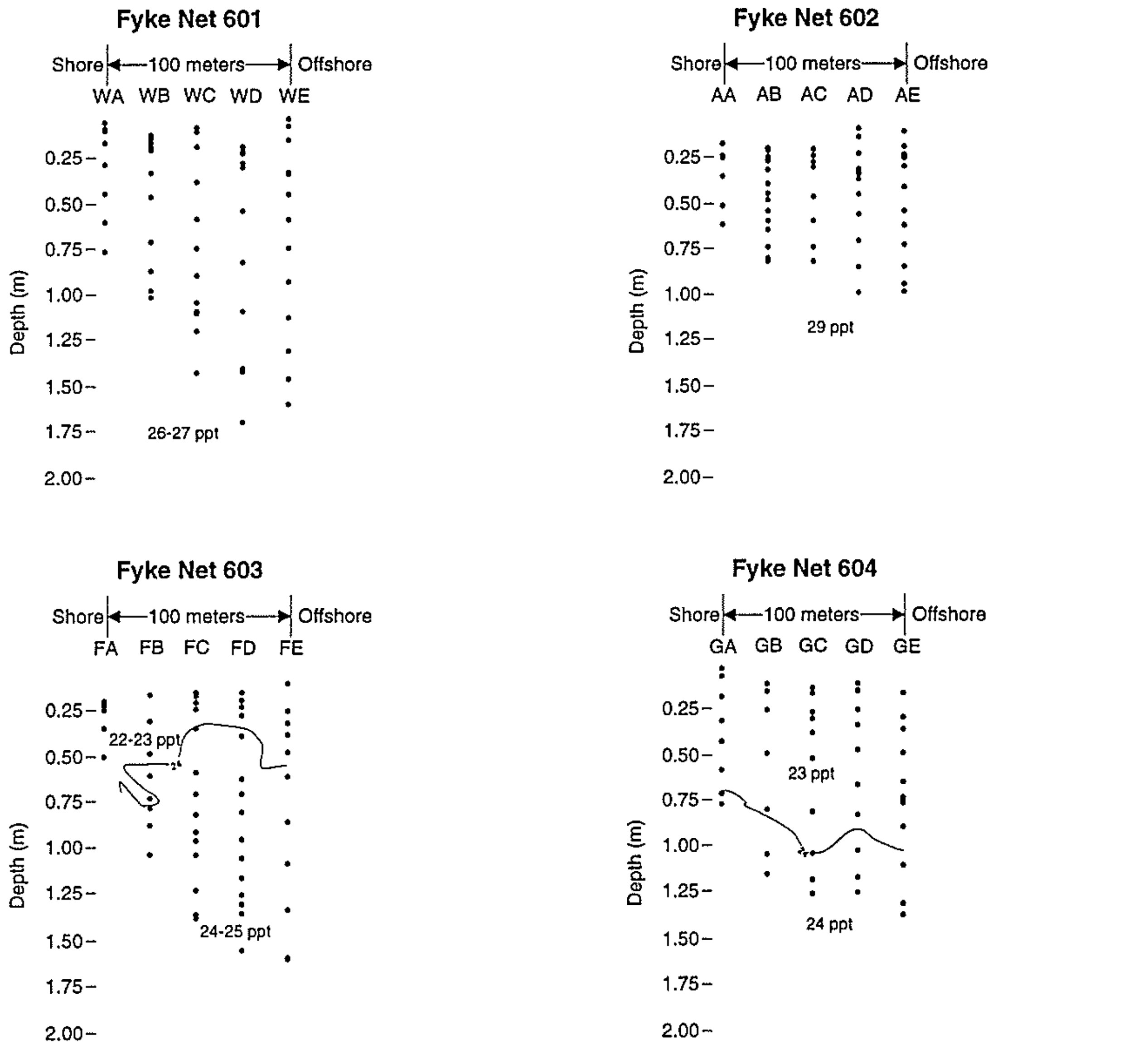

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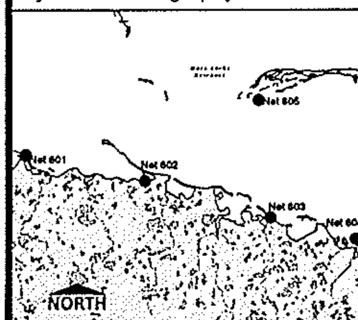
FIGURE 4.19

1999 Physical Oceanography

August 7, 1999
Salinity
(parts per thousand)
Surf Zone
Transects

Notes:
Base map was digitized from USGS 1:63360 Topographic Map by BPXA Cartography.



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5.1 REGIONAL PROCESSES

More than two decades of oceanographic investigations have enabled development of a comprehensive understanding of the regional processes that affect movements and quality of water along the Alaska Beaufort Sea coast. Concepts of coastal boundary layer (CBL) processes, as elucidated by Csanady (1982) for shallow coastal seas, were demonstrated through exhaustive reviews and analyses of available data to be applicable to the nearshore Beaufort Sea (Niedoroda & Colonell 1989, 1990; Colonell & Niedoroda 1990; Colonell et al. 1992).

Three forcing factors drive the circulation of the coastal ocean: wind stress, tides, and horizontal pressure gradients. Along the Beaufort Sea coast, winds are generally alongshore with easterlies occurring about twice as frequently as westerlies during the open-water season. Because wind stress is proportional to the square of the wind speed, high winds (storms) tend to dominate the circulation. Winds along the Alaska Beaufort Sea coast are rarely calm and the typical summer usually includes several storm episodes, with maximum sustained wind speeds of 25-30 MPH.

Astronomical tides in the Beaufort Sea are small (< 30 centimeters [cm]) and essentially inconsequential as a factor in regional oceanographic processes. Storm "surges" can be large, with sea level displacements of -0.5 to +1.0 meters at the shoreline being relatively common occurrences; however, response times for storm surges are short (< 2-4 hour), such that their effects are limited essentially to that of a quasi-steady sea level displacement, once they are established. Horizontal pressure gradients occur when the densities of nearshore and offshore waters differ significantly. Large influxes of fresh water to the coastal zone produce such density differences, and occur at many locations along the Alaska Beaufort Sea coast at spring breakup and throughout the summer season.

Along the Alaska Beaufort Sea coast, the gentle seabed slope and the relatively large Coriolis acceleration serve to amplify CBL processes beyond what is familiar in lower latitudes. Csanady (1982) demonstrated that the CBL consists of two distinct zones, an inner zone along the shoreline within which the effects of friction exceed those of Coriolis acceleration (i.e. earth rotation) with the result that surface transport is aligned with the wind direction. Niedoroda and Colonell (1989) presented scale arguments based on available hydrographic data to show that the inner, friction-dominated, portion of the CBL extends from the shoreline to depths of only 4-5 m at 70° north latitude. At lower latitudes, this portion of the CBL typically extends to depths of 20 meters or more.

Further seaward, Coriolis effects become progressively more effective in determining the response of water masses to wind stress and horizontal pressure gradients, resulting in the well-known "Ekman effect" that is described most textbooks on oceanography (e.g. Neumann and Pierson 1966). The Ekman effect is a manifestation of the effect that the Earth's rotation has on fluid movements, such that surface transport is "geostrophic" and thus aligned nearly perpendicularly to the wind direction. The demarcation between the inner (friction-dominated) and outer (geostrophic) zones of the CBL, which occurs in water depths of only 4-7 meters at Beaufort Sea latitudes, is a transition zone where, under *easterly* winds, the *divergence* of shore-perpendicular surface transport produces local *upwelling*. Conversely, under *westerly* winds, the *convergence* of shore-perpendicular surface transport produces local *downwelling*.

Coastal boundary layer processes occur on a regional scale, so they have important implications to the general circulation and distribution of water masses in the coastal Beaufort Sea. The scale, magnitude, and development rate of the upwelling / downwelling processes are controlled by the wind speed, wind direction (relative to the shoreline), and wind duration, as well as the water depth and thicknesses of the water mass layers. Because of the higher latitude, effects of the upwelling / downwelling processes are experienced at shallower depths (i.e. 4-5 meters) and thus much closer to the shoreline than at lower latitudes. Exhaustive reviews and analyses of available oceanographic data have documented the occurrence of these CBL processes from Prudhoe Bay westward through Simpson Lagoon (Colonell and Niedoroda 1990) and from the Endicott Development area eastward through Foggy Island Bay to Brownlow Point (Niedoroda and Colonell 1990).

The present data set for the Lions Lagoon region provides additional documentation of the pervasive influence of regional oceanographic processes along the Alaska Beaufort Sea coast. Early season hydrography (Figs. 4.4 to 4.7) is typical of other Beaufort coastal areas in that it indicates the presence of a brackish water mass lying along the shoreline. This water mass is the result of ice melt and ample spring breakup flows from nearby rivers (Canning and Staines), as well as tundra streams and ice melt.

Figures 5.1 to 5.3 illustrate the variation of salinity at three locations in Lions Lagoon throughout the summer season at a distance of about 1 km from the mainland shoreline. Early summer westerlies and the strong shoreward horizontal pressure gradient, created by the large density difference between offshore and nearshore waters, served to hold the brackish water mass against the shoreline and to preserve its character until early July. A series of east wind events then promoted upwelling of cold marine water into the lagoon several times during the summer in a manner consistent with that observed elsewhere at numerous locations along the Beaufort Sea coast.

Although river discharge served to freshen surface waters of Lions Lagoon at least twice after spring breakup during late July and early August, this effect was overpowered by the repeated upwellings caused by several strong east wind events during the second half of the summer. The lagoon remained somewhat fresher to the west of Mary Sachs entrance, than to the east where bottom salinities typical of deeper marine waters (>30‰) persisted after early August.

The oceanographic data set assembled for the Lions Lagoon – Point Thomson area demonstrates a pattern of hydrographic behavior that is entirely consistent with the understanding of coastal ocean dynamics that was promulgated by Csanady (1982). The verification of Csanady's theoretical framework for the coastal boundary layer was demonstrated by Colonell and Niedoroda in the several papers already cited by its application to the coastal Beaufort Sea. Namely, regional oceanographic processes, which are driven primarily by the wind, and the influence of nearby freshwater discharges from rivers and streams, are responsible for establishing the seasonal hydrography of Lions Lagoon, in a manner that is consistent with that observed at other locations along the Beaufort Sea coast.

5.2 SURF ZONE AND DOCKING STRUCTURE WATERS

For the past 20 years most of the physical oceanography studies that accompanied fish population and migration studies focused efforts to describe the nearshore waters with minimal efforts to observe conditions immediately adjacent to the shoreline–the surf zone. The Alaska Department of Fish and Game (ADF&G) requested a survey of the surf zone waters to ascertain that these waters have a similar character as the nearshore waters typically studied. The surf zone survey component of this study addressed this concern by collecting vertical CTD profiles along 100 meter transects that extended seaward from the four mainland fyke nets.

The surf zone survey did not encounter a band of water that was unique from the waters found offshore in the docking structure baseline survey. The results indicated that there was little difference in the water column structure or salinity. Typically, during periods of significant fresh water input from the Staines River, the fyke net transects mirrored the surface layer conditions described in the docking structure baseline survey. The gradual increase in salinity toward the west noted in the docking structure baseline surveys also was evident in the surf zone surveys.

As the influence of the Staines River discharge decreased, the surf zone transects occasionally encountered a very thin (0.25 meter) surface layer of fresh water that was not noted in the docking structure transects. The easternmost fyke net (No. 604) was approximately 3.7 kilometers (2.3 statue miles) east of the docking structure baseline survey, and encountered fresh water from the Staines River more frequently than any CTD station.

There was the occasional situation where waters adjacent to a fyke net were not similar to the surrounding lagoon waters. However, these situations were short-term and usually restricted to a single net. Typically, this occurred at Net 602 that was located in an area that could naturally confine or trap water behind the Point Thomson spit. Surf zone water temperatures were normally similar or slightly warmer than the water found offshore, and is probably related to solar heating of the relative shallow surf zone water.

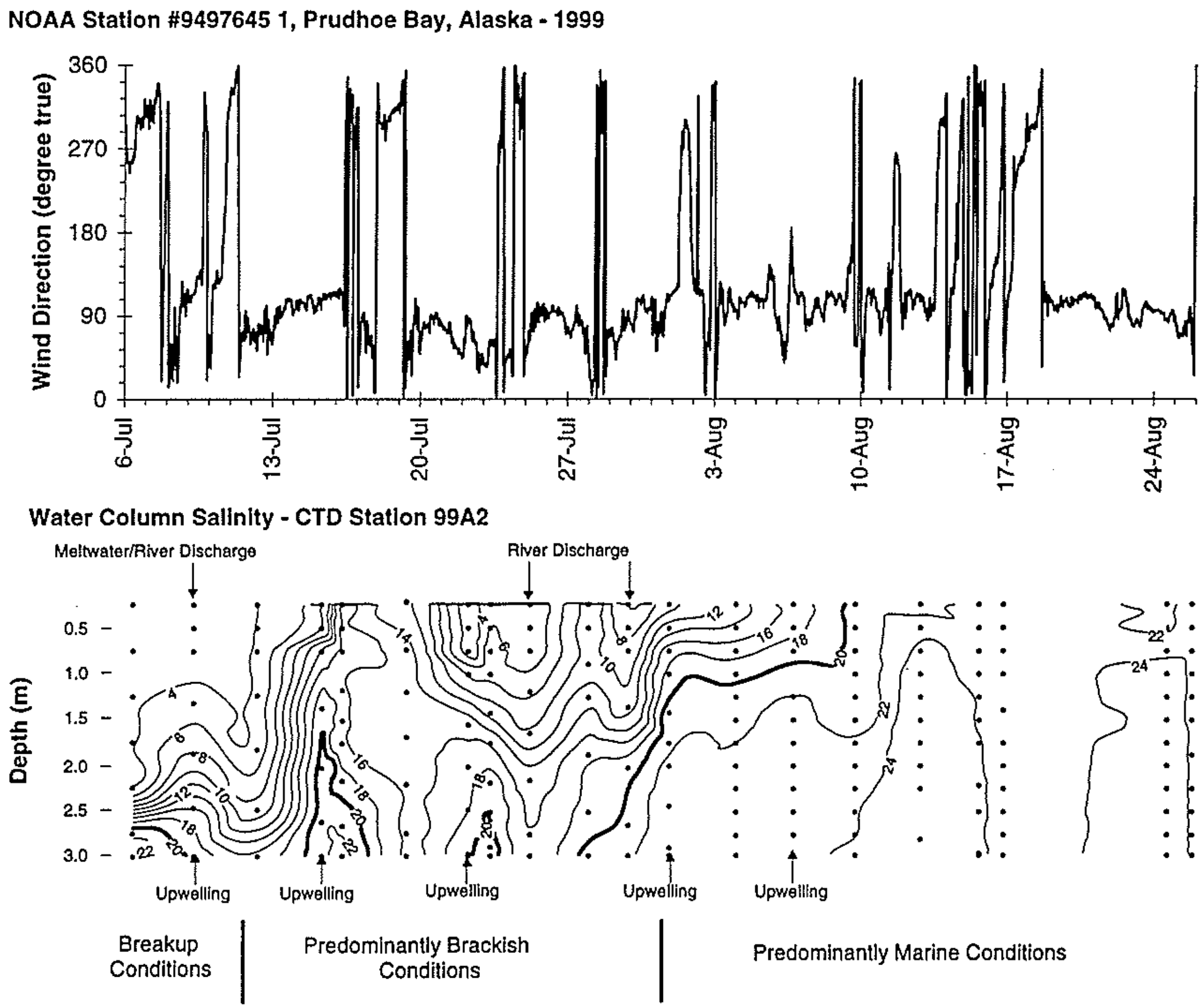

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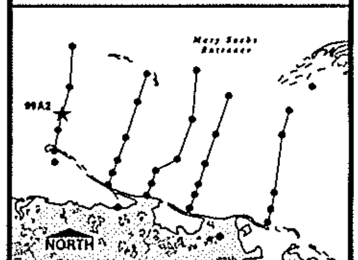
Figure 5.1

1999 Physical Oceanography 99A2 Salinity Time Series (parts per thousand)

Legend:

Contour interval is 2 parts per thousand salinity

Notes:
Base map was digitized from USGS 1:63360 Topographic Map by BPXA Cartography.



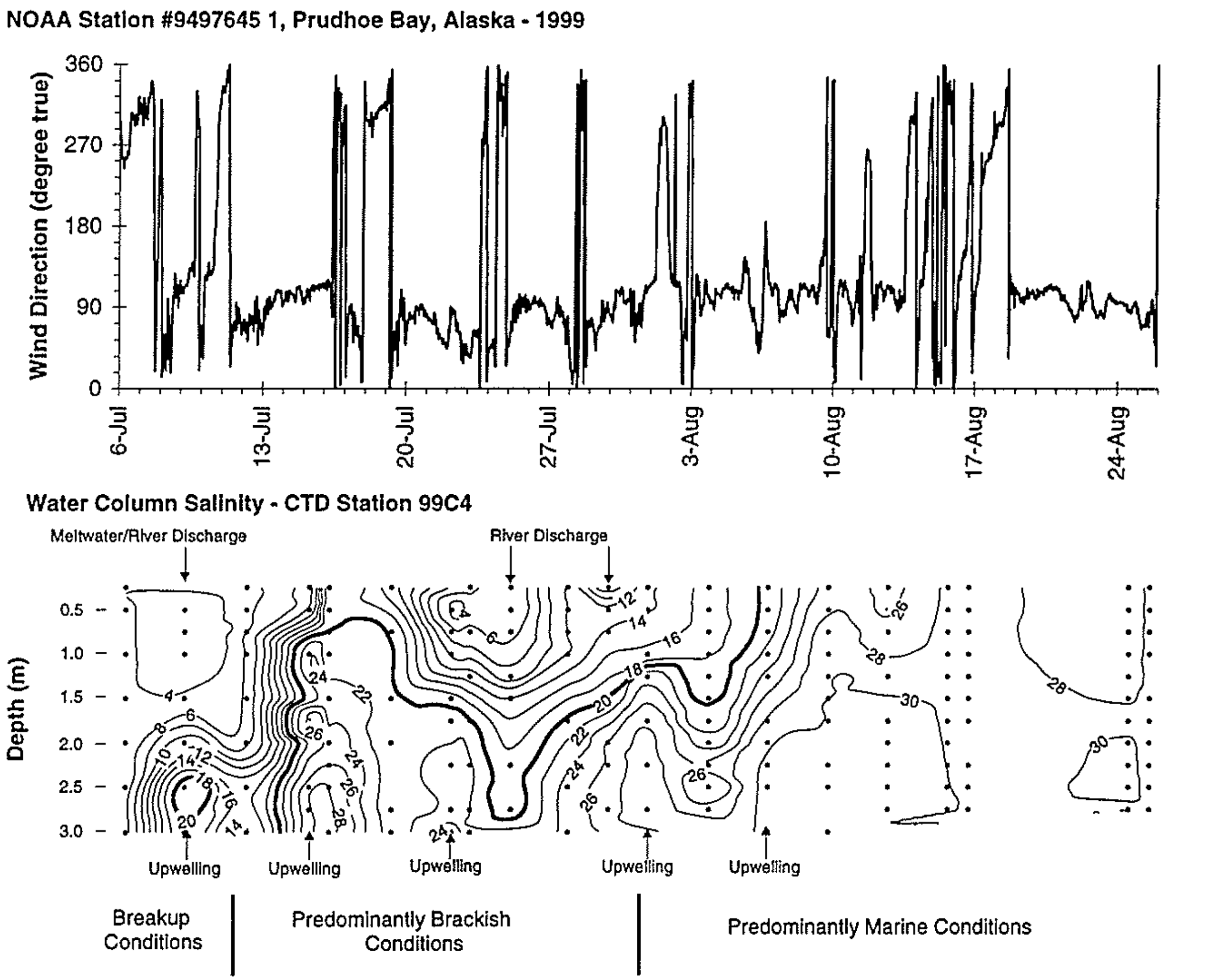


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Figure 5.2

1999 Physical Oceanography 99C4 Salinity Time Series (parts per thousand)

Legend:

Contour interval is 2 parts per thousand salinity

Notes:
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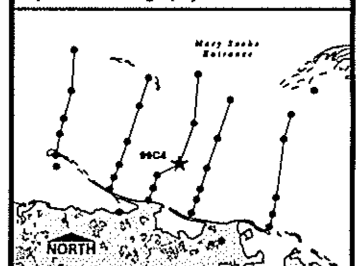

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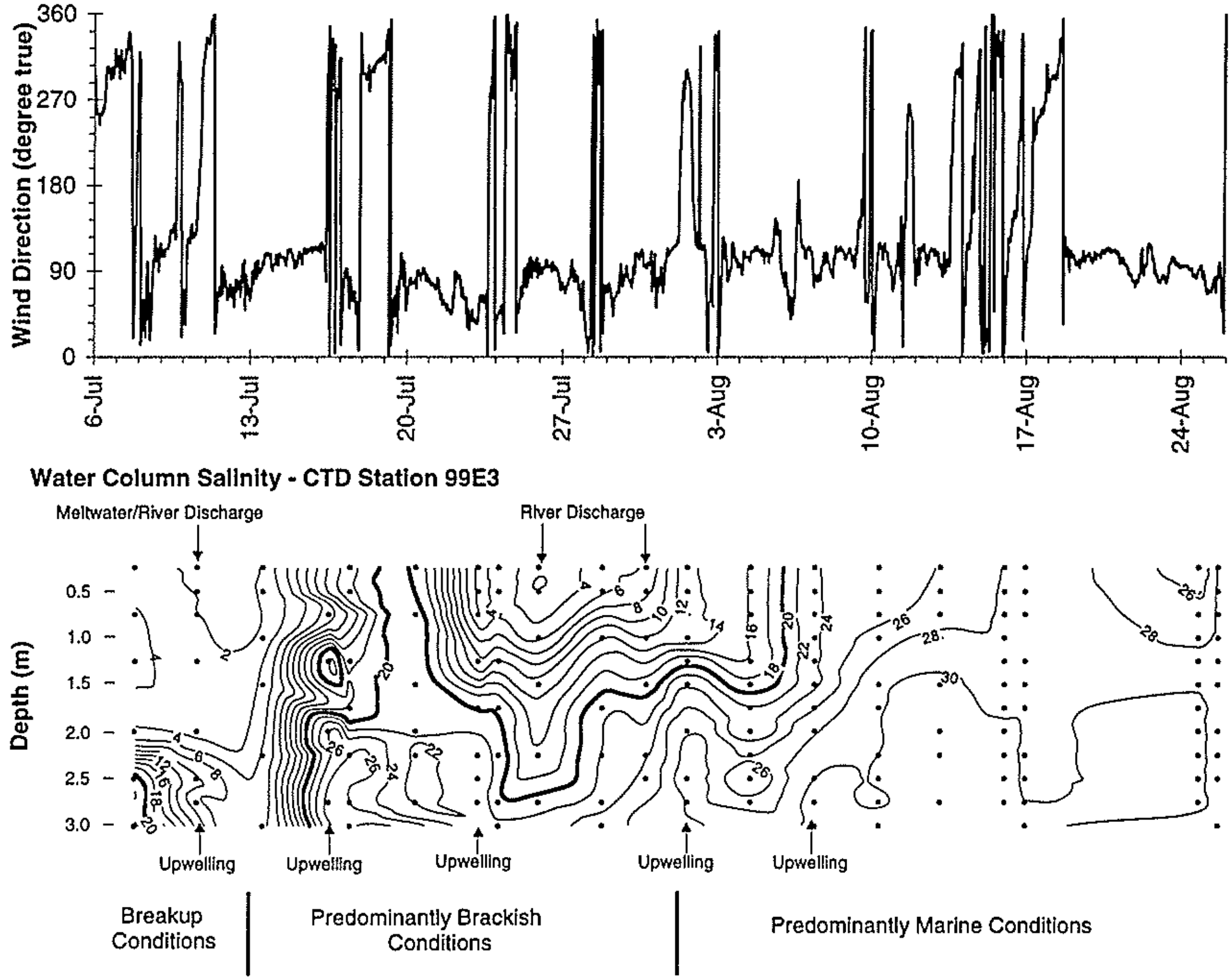

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Figure 5.3

1999 Physical Oceanography 99E3 Salinity Time Series (parts per thousand)

Legend:

Contour interval is 2 parts per thousand salinity

Notes:
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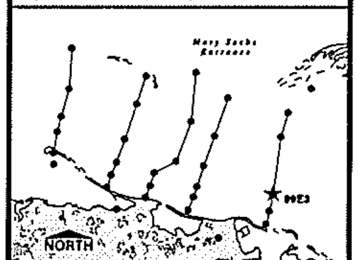

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The 1999 Point Thomson Unit Physical Oceanography/Meteorology Baseline Study confirmed that regional processes govern the water column structure, water movement within the study area. The findings from this study are similar to findings from previous investigations conducted within Lions Lagoon (URS Greiner Woodward Clyde 1999; Kinnetic Laboratories 1983) and other coastal studies conducted along the Central Beaufort Sea (Niedoroda and Colonell 1990).

Two distinct water column sampling survey designs were conducted in 1999: a baseline study that examined (pre-development) conditions surrounding a proposed gravel-filled docking structure; and, a surf zone study that was composed of 100 meter transects extending offshore of the four mainland fyke nets. Notable findings from these 1999 surveys include:

Meteorology:

- Easterly winds persisted for approximately 70 percent of the study. Sustained wind speeds of 25 to 30 MPH were observed several times during the summer.

Water Column Characteristics–Docking Structure Baseline Survey:

- Water salinity was influenced by sea ice melting, local river discharge, and regional upwelling/downwelling phenomena caused by wind stress acting on the water surface. Upwelling of marine (>30‰) bottom waters coincided with periods of sustained easterly winds. During periods of westerly and mixed short-term easterly/westerly winds, downwelling was observed and typically resulted in brackish water conditions within the study area.
- The study area was dominated by fresh waters associated with sea ice melting during the first few days (early July) of the open-water season.
- Stratified, two layer structure was evident throughout the study area during mid- to late-July where fresh water input from the Staines River formed a surface layer over brackish (14-25‰) nearshore waters.
- Throughout August, fresh water input decreased and persistent easterly winds initiated upwelling of marine (>30‰) bottom waters which encroached into the lagoon through Mary Sachs Entrance. Once established in the study area, the marine waters persisted to the end of the study.

Water Column Characteristics–Surf Zone (Fyke Net) Survey:

- The surf zone survey did not encounter a band of water along the shoreline that was distinct from the lagoon waters.
- There was little difference in salinity between the waters immediately adjacent to the shoreline and the lagoon waters.

Csanady, G. T. 1982. Circulation in the Coastal Ocean. Environmental Fluid Mechanics Monograph. Reidel Pub. Co. 279 p.

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Colonell, J. M., B. J. Gallaway, and A. W. Niedoroda. 1992. Environmental Effects of Beaufort Sea Causeways, p. 958-974. In: Coastal Engineering Practice '92. Proceedings of the Waterways Division, American Society of Civil Engineers, Long Beach, CA.

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Niedoroda, A. W. and J. M. Colonell. 1990. Endicott area oceanographic processes. In: The 1988 Endicott Development Fish Monitoring Program – Analysis of 1985 – 1987 data. Report to BP Exploration (Alaska), Inc. by Environmental Science & Engineering, Inc. and LGL Alaska Research Associates, Vol. I, 160 p.

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URS Greiner Woodward Clyde 2000. Point Thomson Unit Area 1999 Physical Oceanography Study: Work Plan, Prepared for BP AMOCO and the Point Thomson Unit Owners, June 25, 2000. URS Greiner Woodward Clyde project number 74-09900007.00.