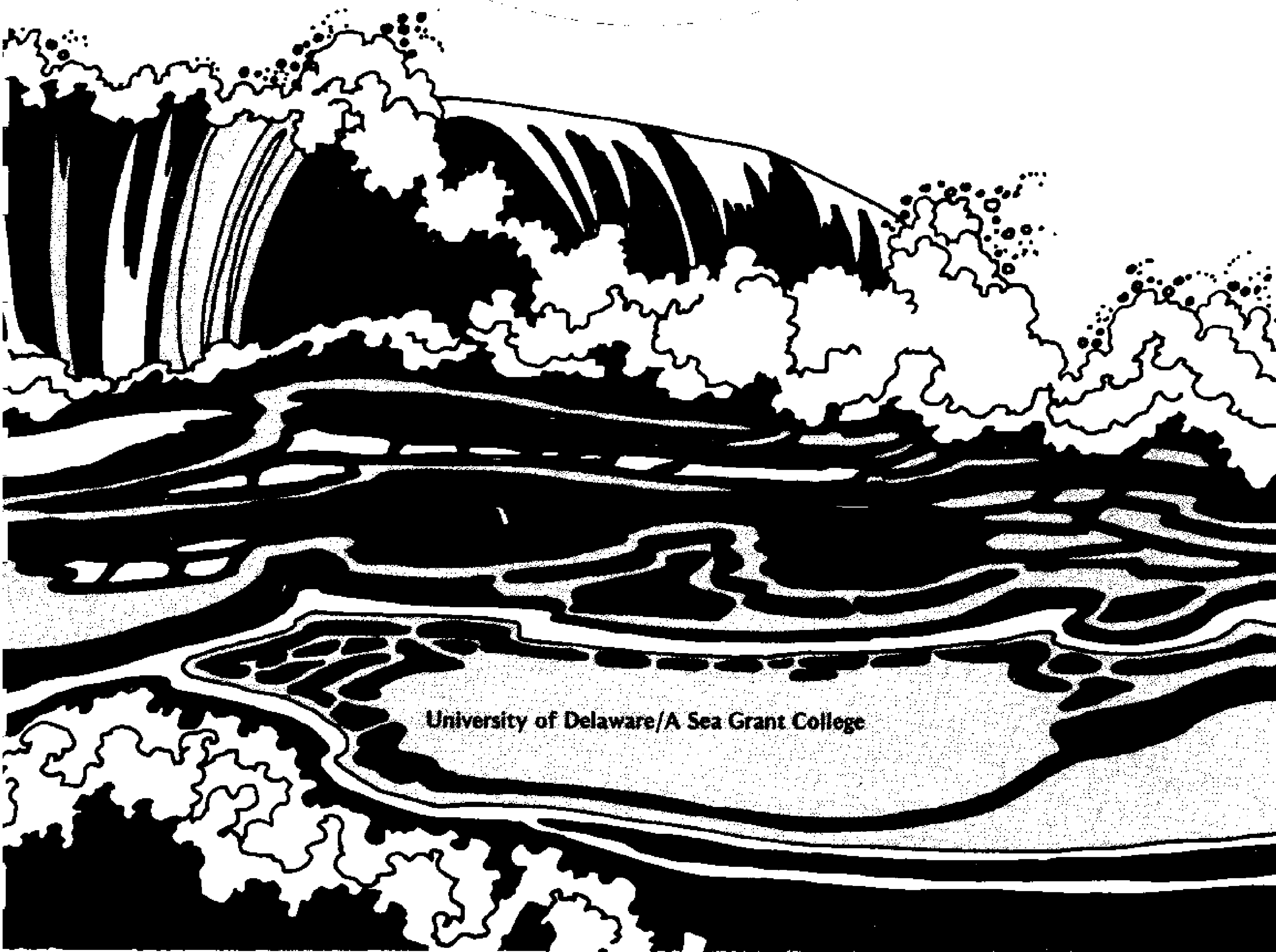
A Delaware Sea Grant Technical Report



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DELAWARE BAY ICE CONDITIONS, 1977

by

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DEL-SG-9-77

Published by
The Delaware Sea Grant College Program
College of Marine Studies
University of Delaware
Newark, Delaware
19711

ACKNOWLEDGMENTS

We wish to thank Mr. Bruce Hooper of Interstate and Ocean Transport Company and the crew members of the tugs which transport barges in the Delaware Estuary for their help in taking measurements of ice thickness and for their observations on the ice conditions in the estuary.

This work is a result of research sponsored by NOAA Office of Sea Grant, Department of Commerce. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notation that may appear hereon.

INTRODUCTION

As a result of the extreme cold weather during this past winter (Fig. 1), an unusually large amount of ice formed in the Delaware Bay and River. Although a final estimate of the total damage done by the ice is not yet available, by the first of February an estimated $115,000 in damage and lost time had been suffered by Delaware's crab, clam, and oyster fishermen. The crab industry reported a loss of $99,620 in crabbing days lost, unemployed fishermen and a catch reduced by an estimated 13,333 bushels. Clammers estimated a loss of $5,400 due to 19 fishing days lost as a result of the cold weather. The oyster fishermen reported the loss of about 1,000 oyster stakes which were destroyed by ice causing $10,000 in damage.* Additional reported damage to coastal facilities brought the total to an estimated $491,000. Large ship and barge traffic continued normally during the cold spell. However the Cape May to Lewes Ferry was forced to close for forty days during January and February.

In order to map the extent and type of ice cover, four flights were made over the area from the Delaware Memorial Bridge to the mouth of Delaware Bay. Visual observations were recorded on maps of the area and color and black and white photographs were taken to back up the observations. Two hand-held

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*Delaware State News, Vol. 77, No. 28, February 2, 1977, "Coastal Toll May Hit Million".

35 mm cameras were used to obtain both vertical and low oblique photographs. One camera was loaded with color slide film with a 1A haze filter mounted over the lens. The other camera was loaded with black and white film.

The following six categories were used to define the observed ice formations:

1. Slush - areas where new ice was forming (Fig. 2)
2. Fast ice - solid ice sheet that forms over shallow water areas along the coast (Figs. 3-5, 11)
3. Large drift ice - variously shaped pieces of ice with a diameter of greater than one meter (Figs. 6-9)
4. Small drift ice - pieces of ice smaller than one meter in diameter (Figs. 9 and 10)
5. Pack ice - solid ice cover formed when drift ice undergoes pressure forces along with alternating breaking up and refreezing (Figs. 11 and 12)
6. No ice

ICE CONDITIONS

FLIGHT 1
19 January 1977 (Figure 13)

Winds: West-northwest at 20 knots
Tidal stage: Two hours after maximum ebb at the mouth (Figure 14)

Fast ice was observed along 60% of the Delaware coastline. In all cases this ice did not extend for more than one-half nautical mile from the coastline. One hundred percent of the New Jersey coastline was lined with fast ice. In most areas it was only a narrow strip but in the shallow areas it extended over a nautical mile from the coastline. At no place was there 100% shore to shore coverage of ice. Large and small pieces of drift ice were observed flowing out of the Bay around both Capes with the ebbing tide. Large drift ice extended as far as twelve miles south of Cape Henlopen and six miles offshore from Rehoboth Beach. On the Bay, strong west-northwest winds kept the Delaware side clear of large drift ice. Small drift ice was observed flowing from many of the small rivers which empty into the Delaware Bay. Almost all of the observed pack ice was located on the New Jersey side. This was due to the strong westerly winds that had been blowing for several days prior to the flight. The winds forced the drift ice to pile up along the New Jersey coast where it froze together to form the pack ice. Small areas of pack ice were also observed around Cape Henlopen and north of the Lightering area. Large ship and barge traffic was continuing normally as the shipping lanes were either free of ice or contained large drift ice. No small vessels, such as commercial fishermen, were observed.

FLIGHT 2
1 February 1977 (Figure 15)

Winds: West at 25 knots
Tidal stage: Maximum ebb at the mouth (Figure 16)

Since the first flight, the area experienced a slight warming trend until the 28th of January when a high of 44°F was reached. Mean temperatures during this time remained around the mid-twenties. On the 29th of January a new wave of cold air moved across the area causing the daily highs to reach only the mid- to upper twenties through the first of February. Because of the warming trend, overall ice conditions in the Bay and River were much improved over the first flight. Seventy-five percent of the fast ice along the Delaware coast was gone. Most of the fast ice was located north and south of the opening to the Chesapeake and Delaware Canal. Most of the New Jersey coastline still had fast ice. The only area which was free of ice was just west of Egg Island Point. All of the drift ice was toward the New Jersey side, due to the westerly wind, with most of it located south of Reedy Island.
Drift ice was also observed flowing out of the Bay around Cape May. It extended approximately ten nautical miles northeast of the Cape and 3-5 nautical miles from shore. Pack ice was again found only on the New Jersey side. It had now formed a continuous strip from the Delaware Memorial

Bridge to Cape May. Due to the new cold wave which moved in three days before the flight, a large area of slush was observed. It started east of Cedar Swamp and extended south-southwestward to just north of Cape Henlopen. Ship and barge traffic was not hampered by the ice but again, no small vessels were observed.

FLIGHT 3
7 February 1977 (Figure 17)

Winds: Northwest at 25 knots
Tidal stage: Two hours after maximum flood at the mouth (Figure 18)

The cold air which moved in on the 29th of January lingered over the area. Although the temperatures did get above freezing on several days, the mean temperature ranged from the high teens to mid-twenties. Due to this cold spell, ice conditions were worse than during either of the previous flights. Approximately 80-90% of the area north of the Lightering Area exhibted some type of ice cover. Sixty to seventy percent of the area south of there was covered by some type of ice. The Delaware coastline remained free of fast ice except for areas around Cape Henlopen, Augustine Beach, and New Castle. The New Jersey coastline again had 100% coverage of fast ice from the Delaware Memorial Bridge to Cape May. Drift ice was found extensively throughout the Bay and River. Some drift ice was also observed flowing out of the Bay around Cape May where it was found at least ten nautical miles east of the Cape. The pack ice now extended in a wide belt along the entire New Jersey side. In some locations it extended across 80% of the river. Other areas of pack ice were observed north of Cape Henlopen and north of the Lightering Area. Four small areas of slush were also observed. Even though conditions were much worse, ship and barge traffic was continuing normally. No small vessels were observed.

FLIGHT 4
11 February 1977 (Figure 19)

Winds: Southwest at 5 knots
Tidal stage: Two hours after maximum flood at the mouth (Figure 20)

The cold spell was finally broken on the 9th of February as temperatures began to rise into the high 40s, and the mean temperature stayed above freezing. Due to the warm temperature ice conditions were greatly improved over the previous mission. The Delaware coast was completely clear of fast ice. Fast ice along the New Jersey coast was limited to small coves and the area north of Cape May. Drift ice made up 45% of all ice observed. This thickness of the drift ice was reported to be between one and 15 inches, and averaged about 10 feet across. Some drift ice was observed over the shoals off Cape May and flowing out into the ocean for about five nautical miles. No pack ice was observed. The large area of pack ice north of Cape May observed during the previous flights was breaking up, and consisted of very large floes. No new ice was observed. Ship and barge traffic was still continuing. For the first time small vessels were observed. About six were fishing north of Cape Henlopen and another six were observed north of the Lightering Area.

Other Observations

One striking observation made during two of the flights was the effect of fronts on slush and small pieces of ice. Some areas of slush ice had a sharp boundary between them and open water (Figure 2). These usually occurred in areas known to have frontal activity such as the Lightering Area. Due to the amount of ice coverage, no color difference in water masses or foam lines usually associated with fronts were observed. Small pieces of ice behaved similarly. Many times they would be found in long streamers (Figure 21). Although no foam lines were visible, a difference in water color on either side of the ice was present.

Many observations of typical physical characteristics of ice were also made.

1. Dampening effect of the ice, not only on capillary waves but also on larger waves (Figs. 2 and 8)

2. Frost smoke rising off water which is warmer than the air temperature. This was observed at a thermal effluent north of Delaware Bay (Figs. 22 and 23)

3. Thrust lines which result when two pieces of ice are forced together (Figure 24)

4. Thaw holes (Figure 25)

5. Hummocks which form when wave and tidal action break up the ice sheets (Figure 12)

LANDSAT OBSERVATIONS

Introduction

Imagery from two Landsat satellite overpasses were found which show ice formations in the Bay during previous years. The Landsat imagery is produced by the four-channel multispectral scanner (MSS) having the following four bands:

Band 4	0.5-0.6 microns	-	green
Band 5	0.6-017 microns	-	red
Band 6	0.7-0.8 microns	-	near infrared
Band 7	0.8-1.1 microns	-	near infrared

From an altitude of 920 km, each frame covers an area of 185 km by 185 km and has a resolution of about 80 meters.

13 February 1973 I.D. No. 1205-15191 (Figs. 26-27)

The first image was taken on 13 February 1973 (I.D. No. 1205-15191) (Figures 26 and 27). According to the weather data, a four-day cold spell with temperatures below freezing preceded the day of the overpass. This could have been sufficient for ice to form in the calmer shallow areas. As seen in Band 4 (green) (Figure 26) an area of high reflectance is observed between Cape Henlopen and the Inner Breakwater. Band 7 (infrared) (Figure 27) shows the same phenomenon.

19 January 1976 I.D. No. 2362-14540 (Figs. 28-31)

The tidal stage at the time was three hours after maximum flood at the mouth (Fig. 32). Again a large area of high reflectance north of Cape May is noted in all four bands.

Additional analysis will be performed on these as well as images from January and February of this year in the hope of determining:

1. Ice covered with melt water
2. Leads or cracks in the ice
3. Areas of solid and non-solid ice cover.

This analysis will be written in a separate report as soon as the data is available.

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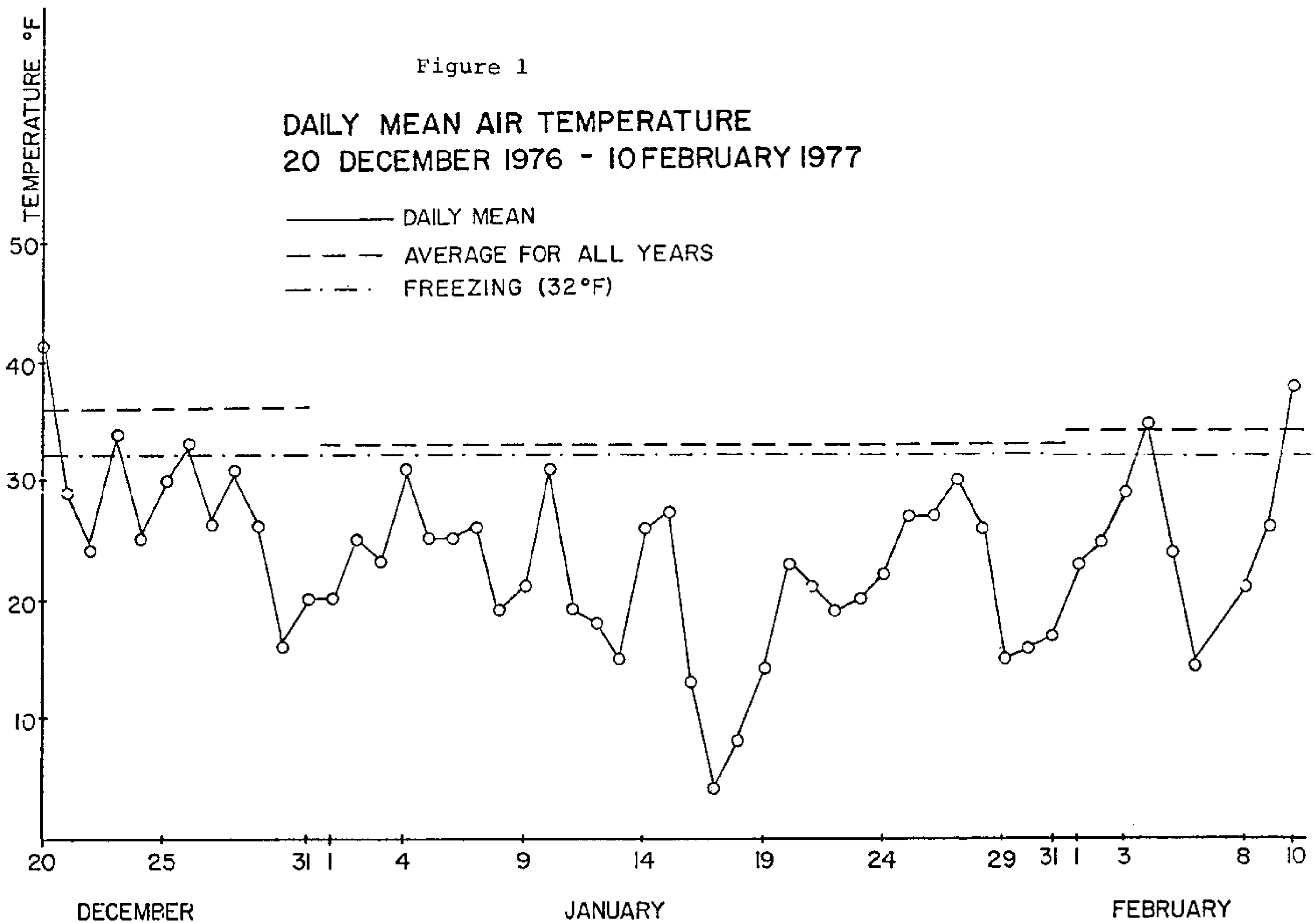


Figure 1
DAILY MEAN AIR TEMPERATURE
20 DECEMBER 1976 - 10 FEBRUARY 1977
DAILY MEAN
AVERAGE FOR ALL YEARS
FREEZING (32°F)
TEMPERATURE °F
50
40
30
20
10
20
25
31
1
4
9
14
19
24
29
31
1
3
8
10
DECEMBER
JANUARY
FEBRUARY

Figure 2: Slush (new ice) as observed on 1 February 1977

Figure 3: Fast ice at Inner Breakwater Harbor, Lewes, on 19 January 1977

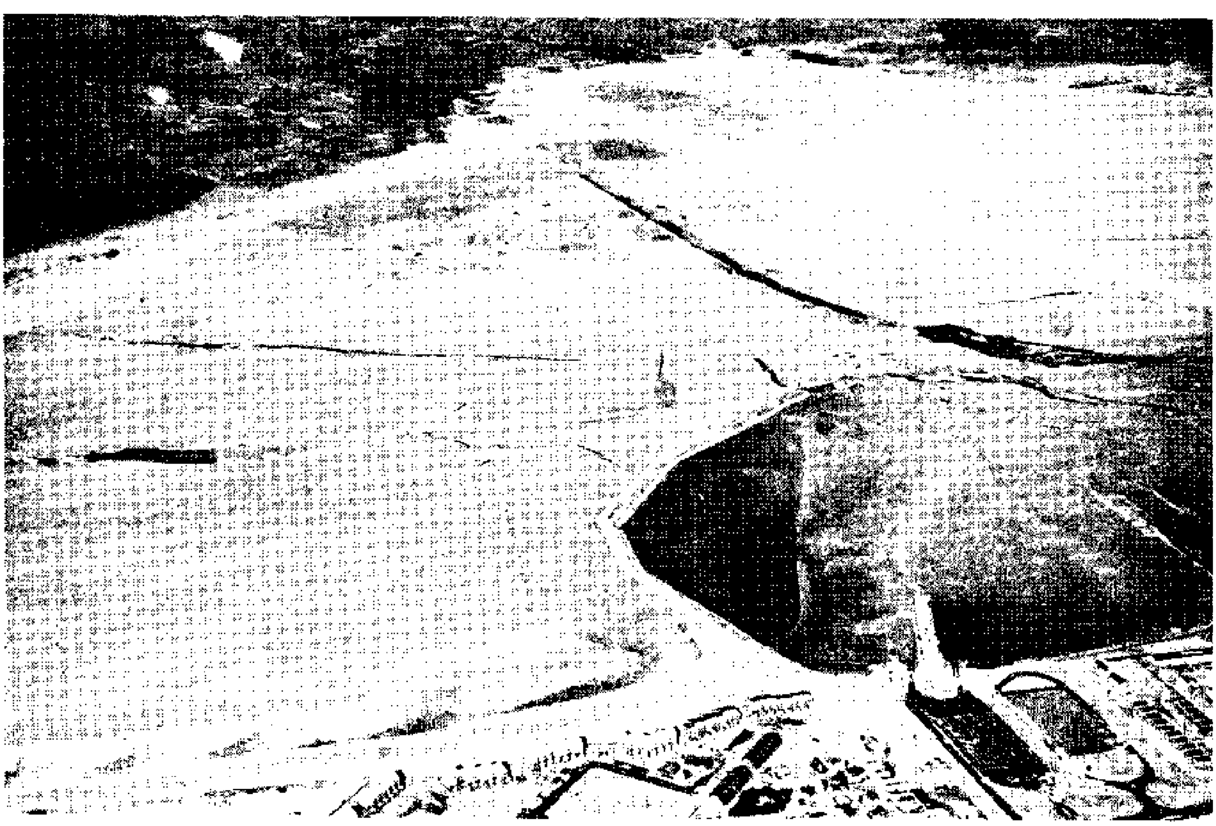


Figure 4: Fast ice at Inner Breakwater Harbor, Lewes, on 1 February 1977

Figure 5: Fast ice at Inner Breakwater Harbor, Lewes, on 7 February 1977

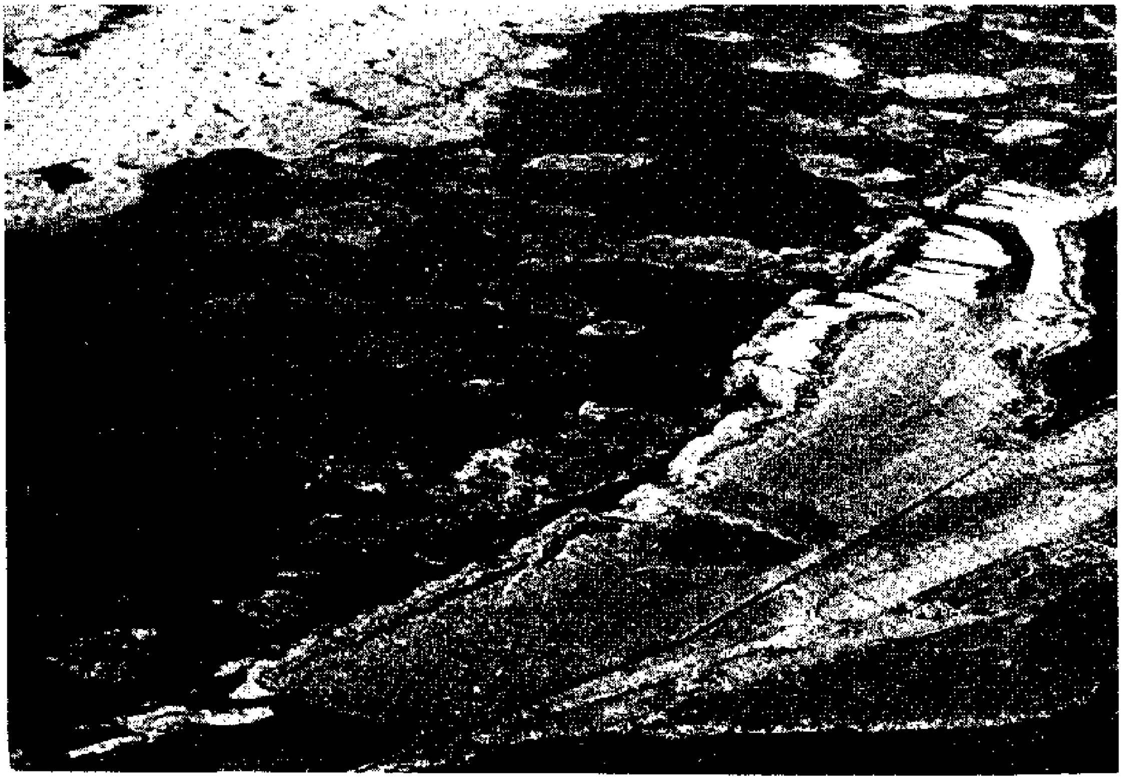


Figure 6: Large drift ice in the Delaware River

Figure 7: Large drift ice in the Delaware Bay

Figure 8: Wave dampening effect of large drift ice (bottom) and small drift ice (top)

Figure 9: Large drift ice with small drift ice collecting on windward side

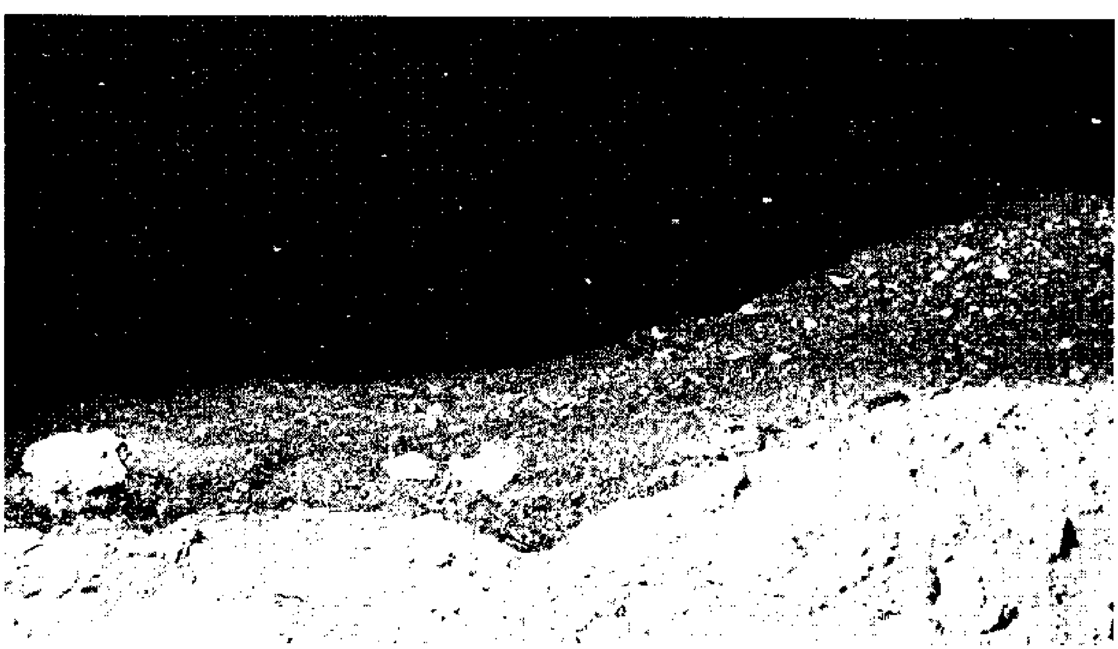
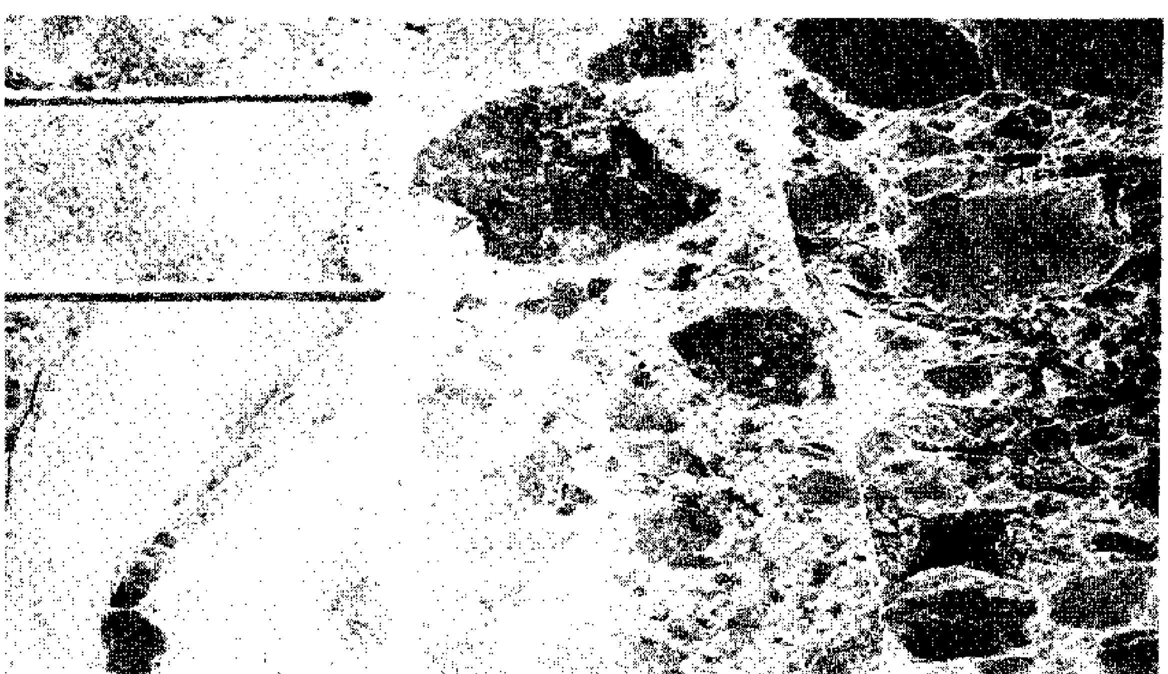


Figure 10: Small drift ice

Figure 11: Fast ice and pack ice near the Cape May Canal



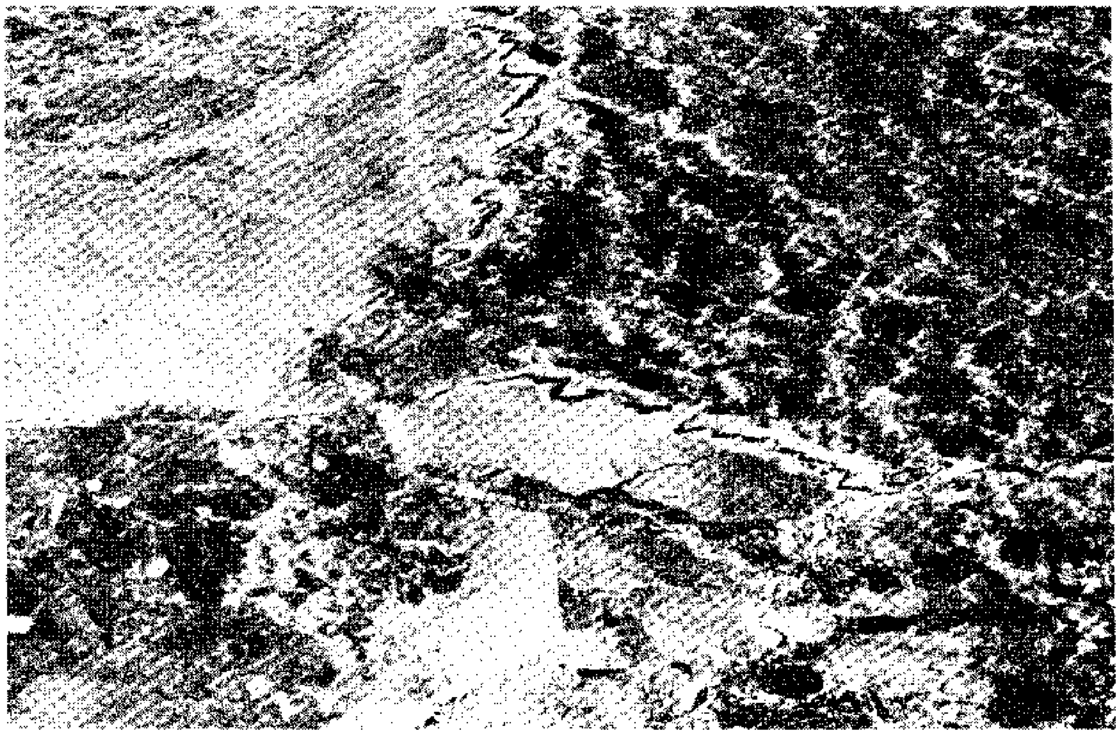


Figure 12: Pack ice with hummocks

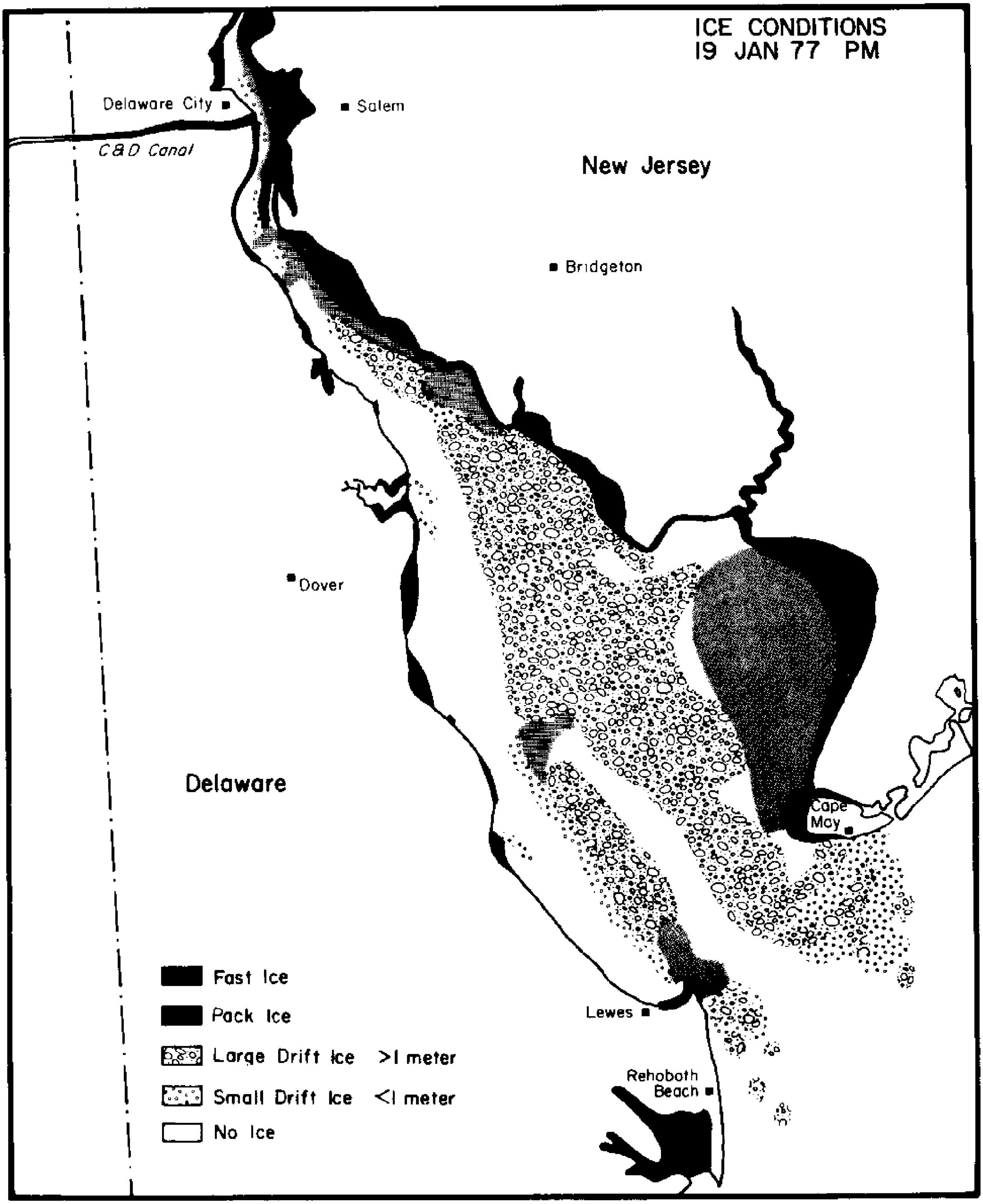


Figure 13: Ice conditions on 19 January 1977

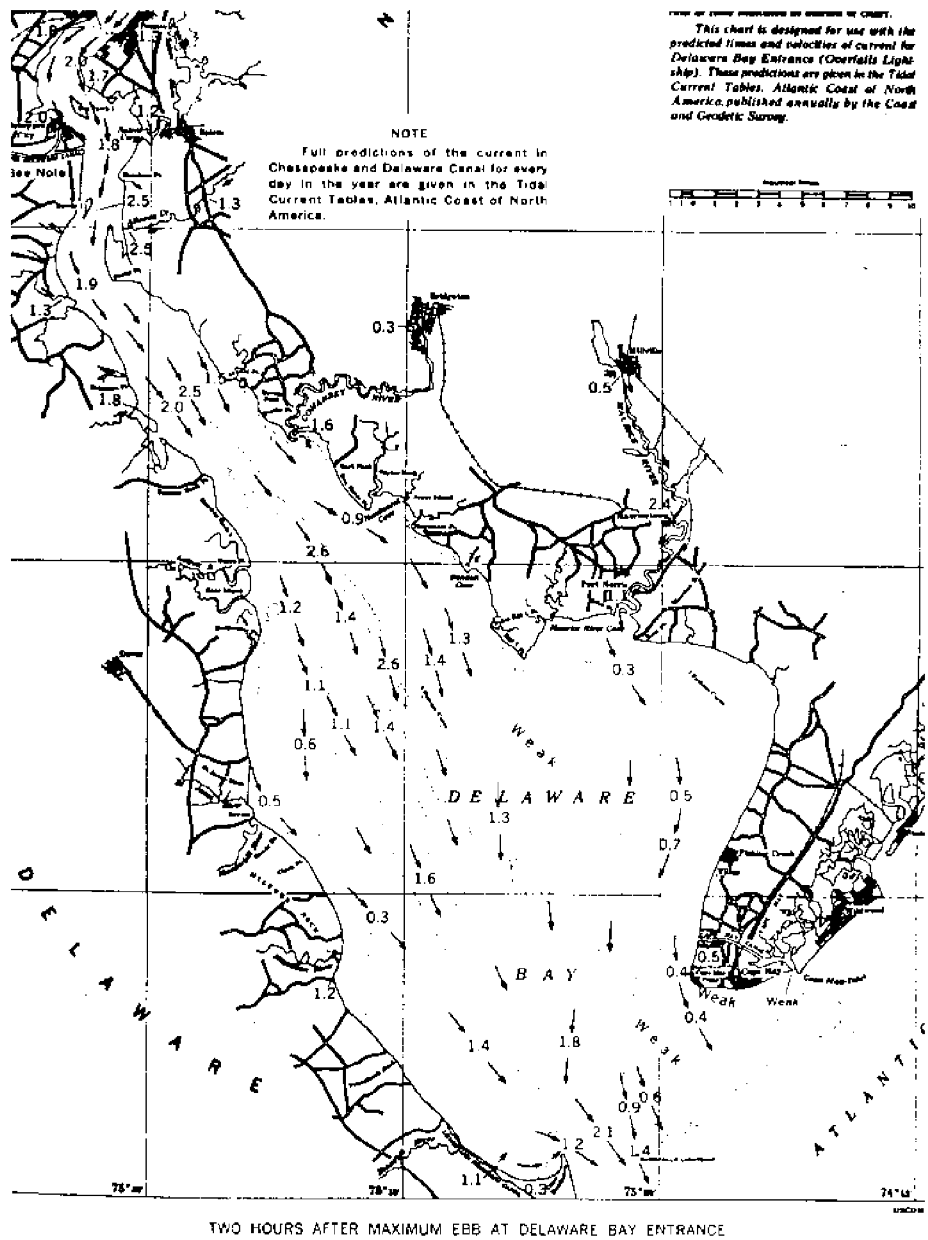


Figure 14: Tidal conditions on 19 January 1977

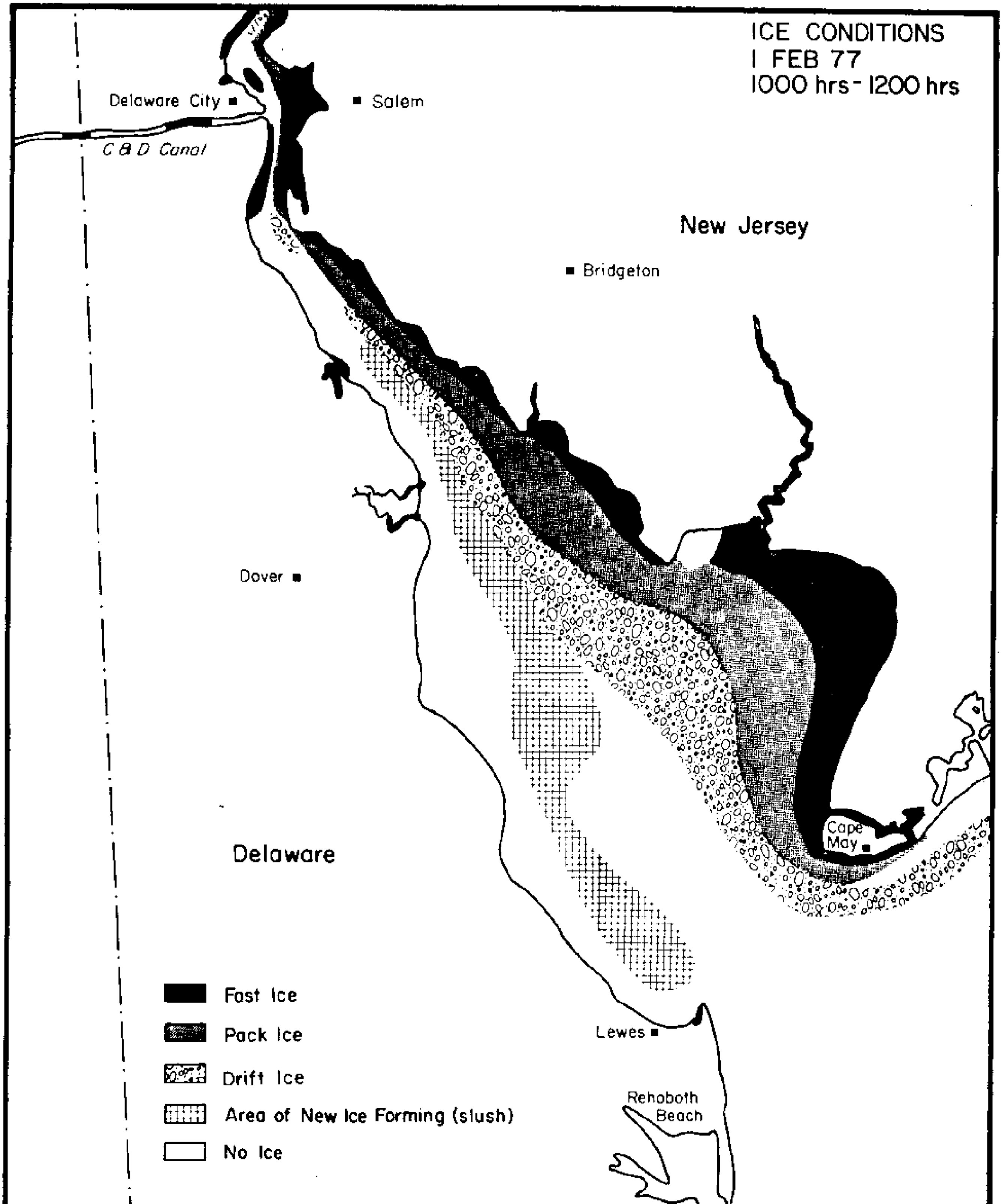
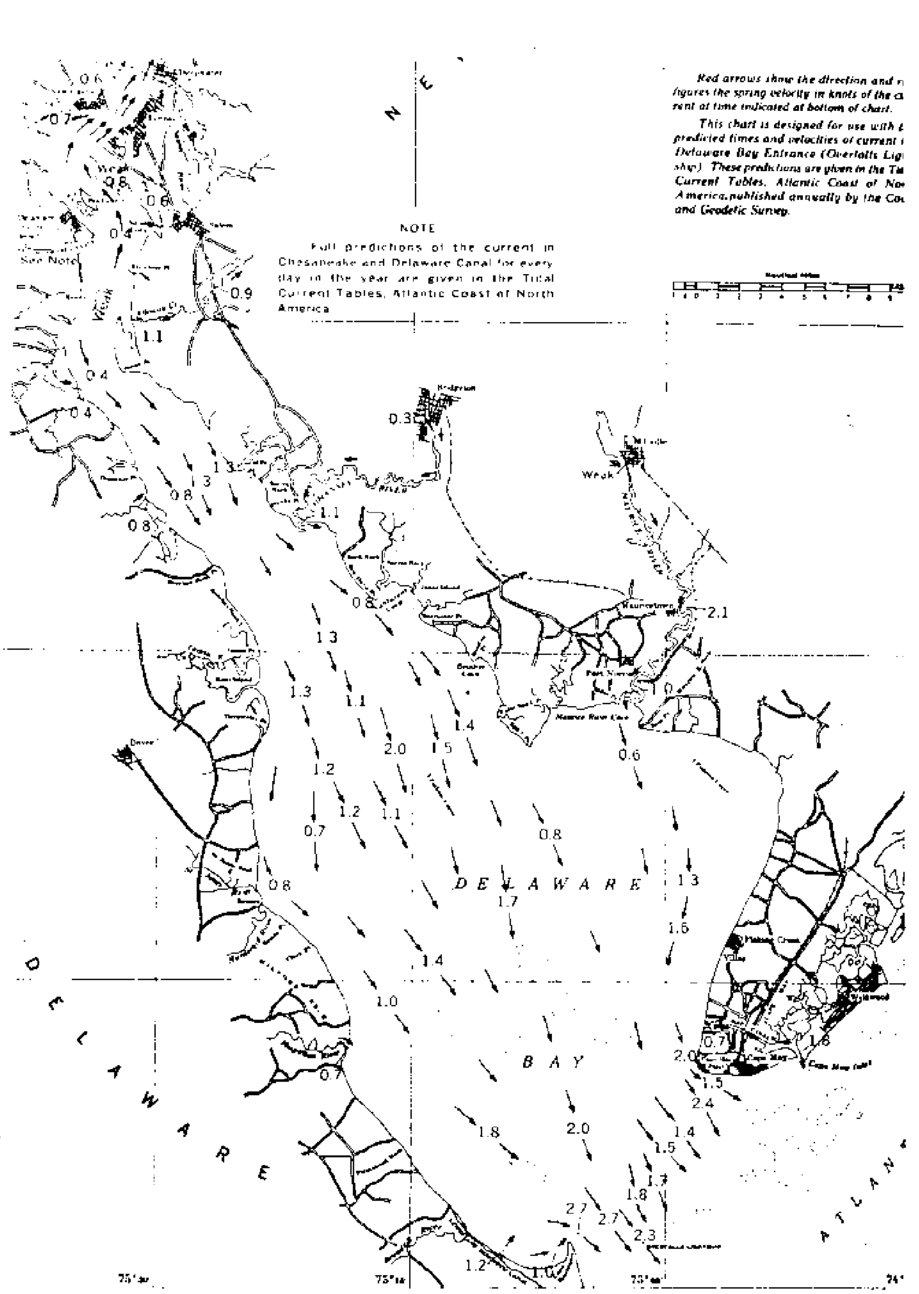


Figure 15: Ice conditions on 1 February 1977



MAXIMUM EBB AT DELAWARE BAY ENTRANCE

Figure 16: Tidal conditions on 1 February 1977

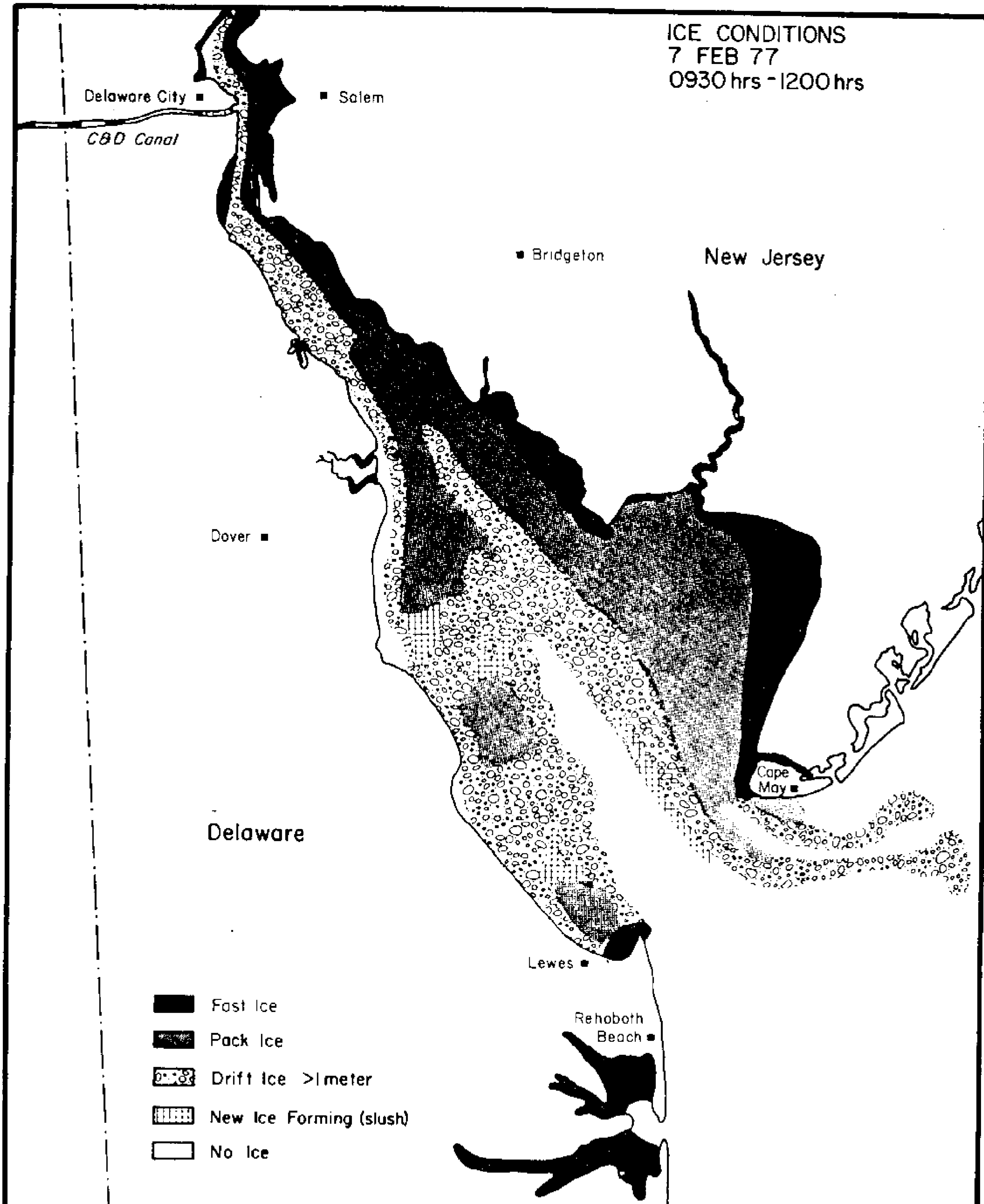


Figure 17: Ice conditions on 7 February 1977

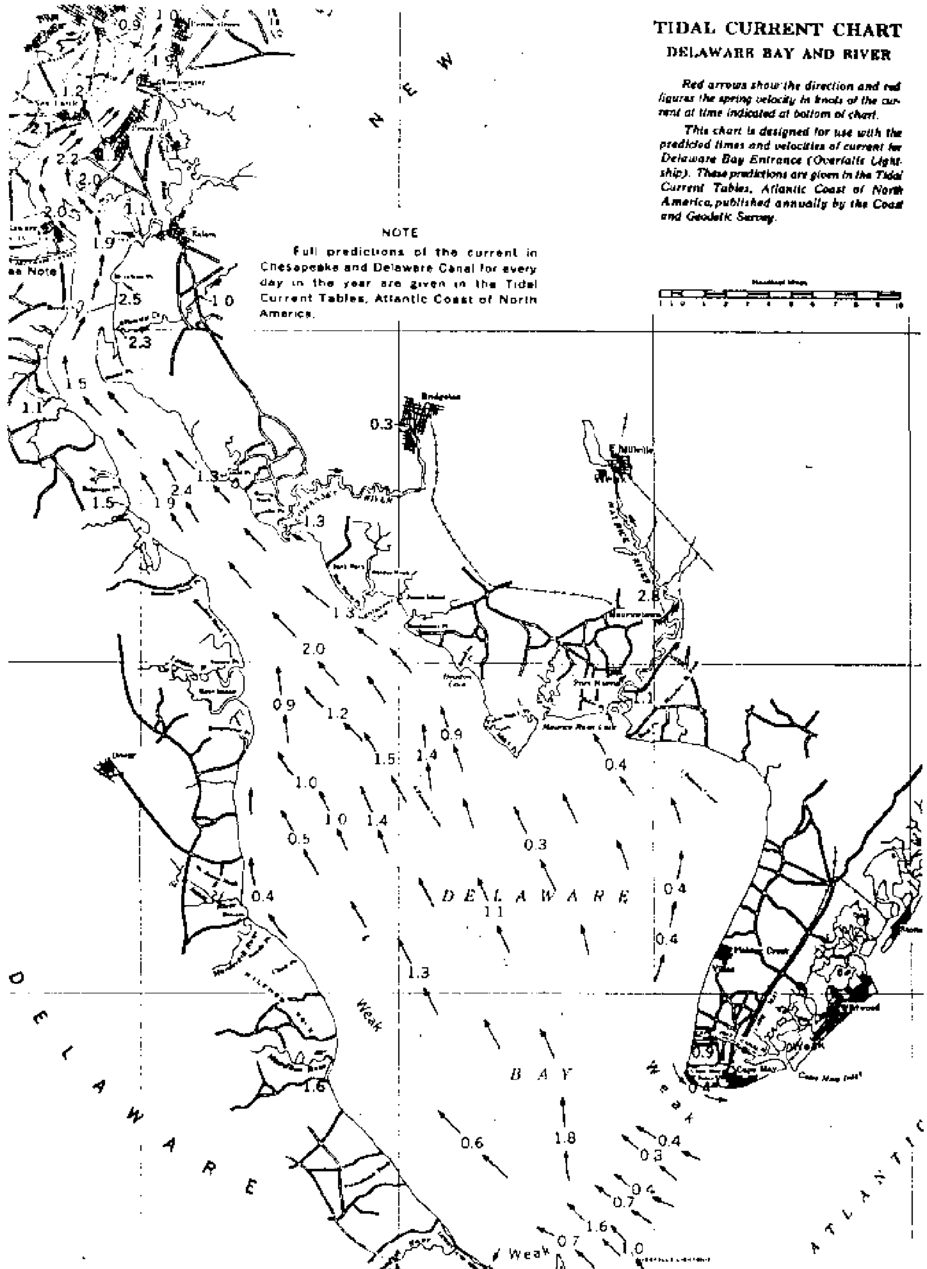


Figure 18: Tidal conditions on 7 February 1977

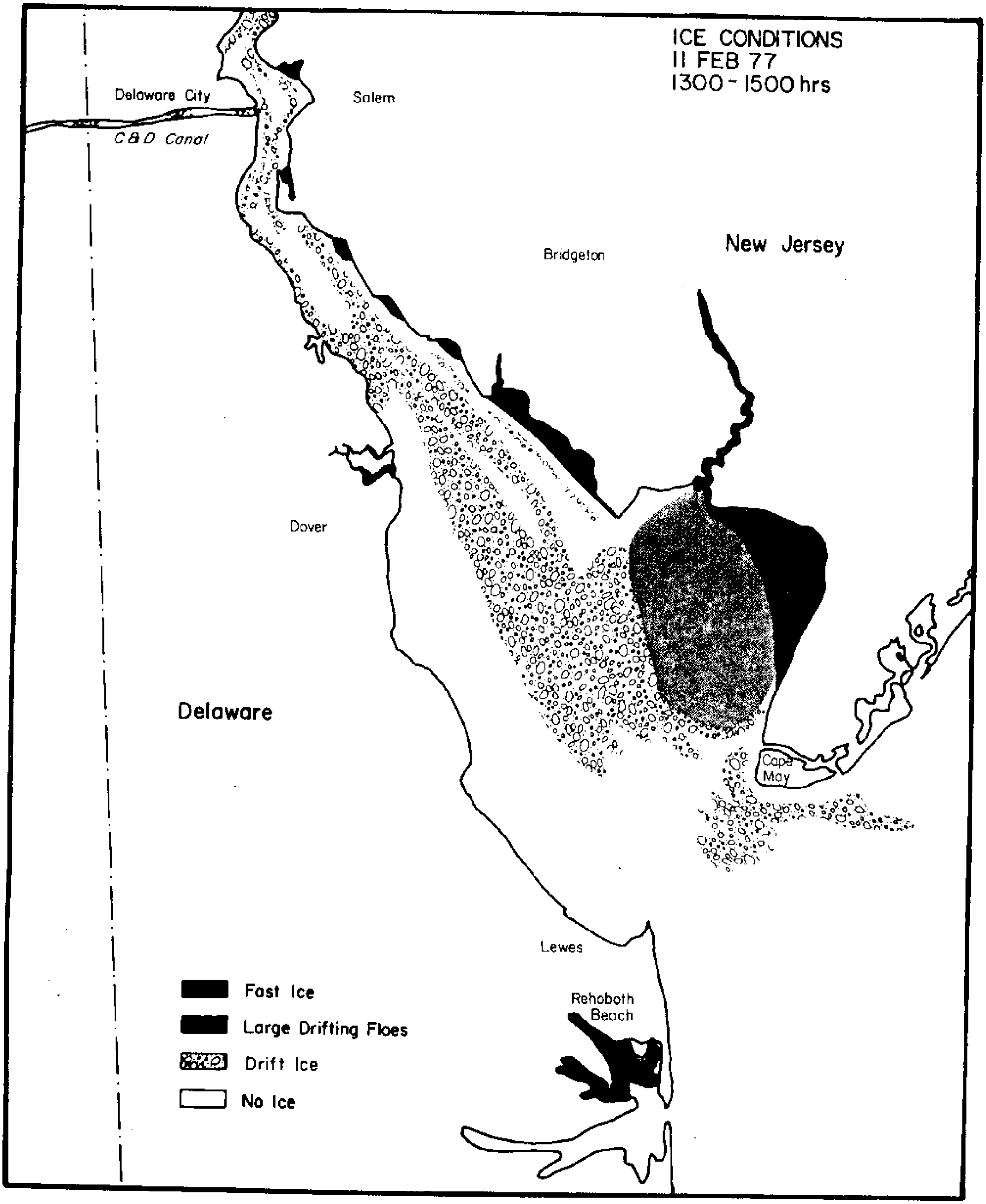


Figure 19: Ice conditions on 11 February 1977

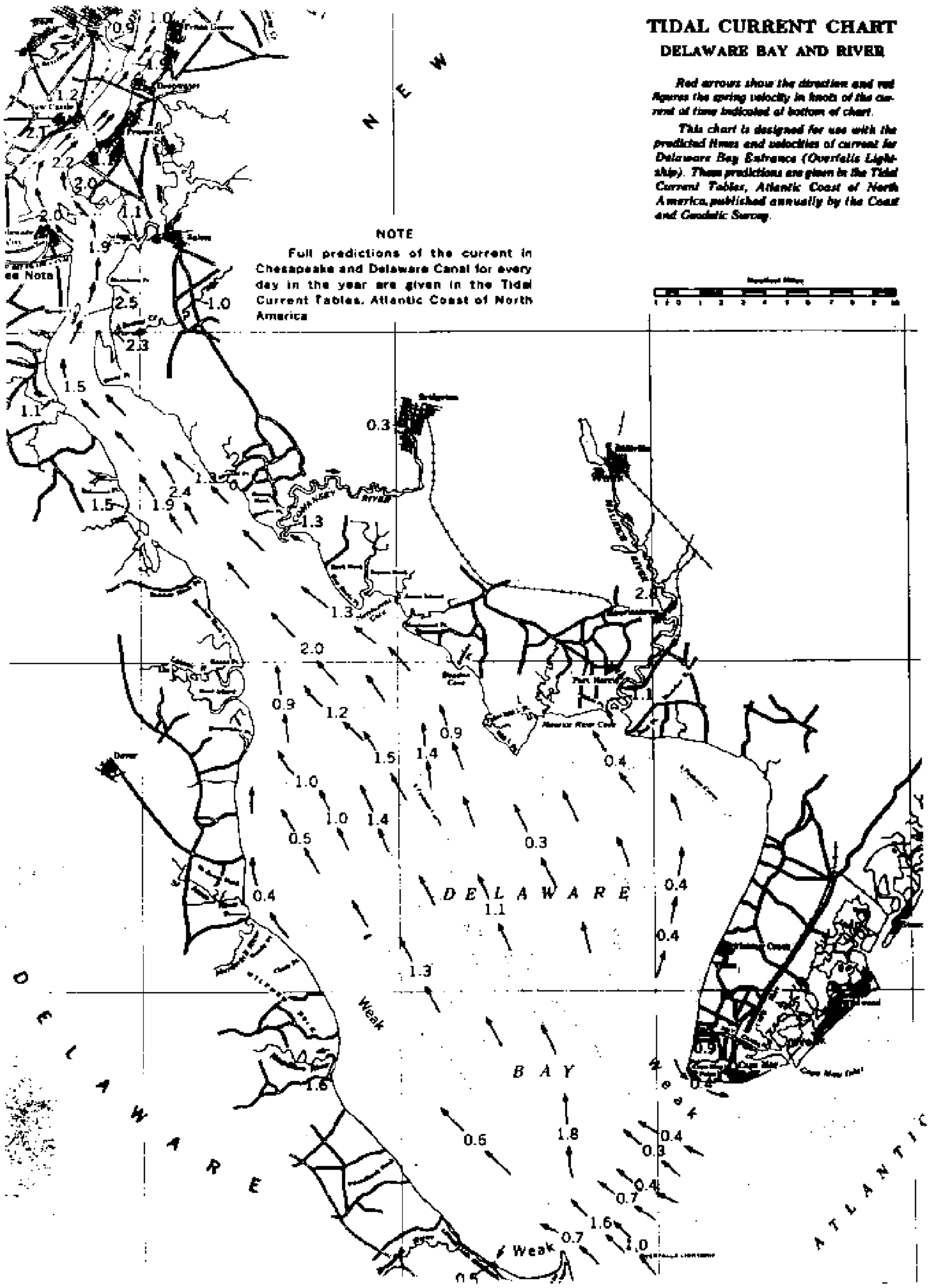


Figure 20: Tidal conditions on 11 February 1977

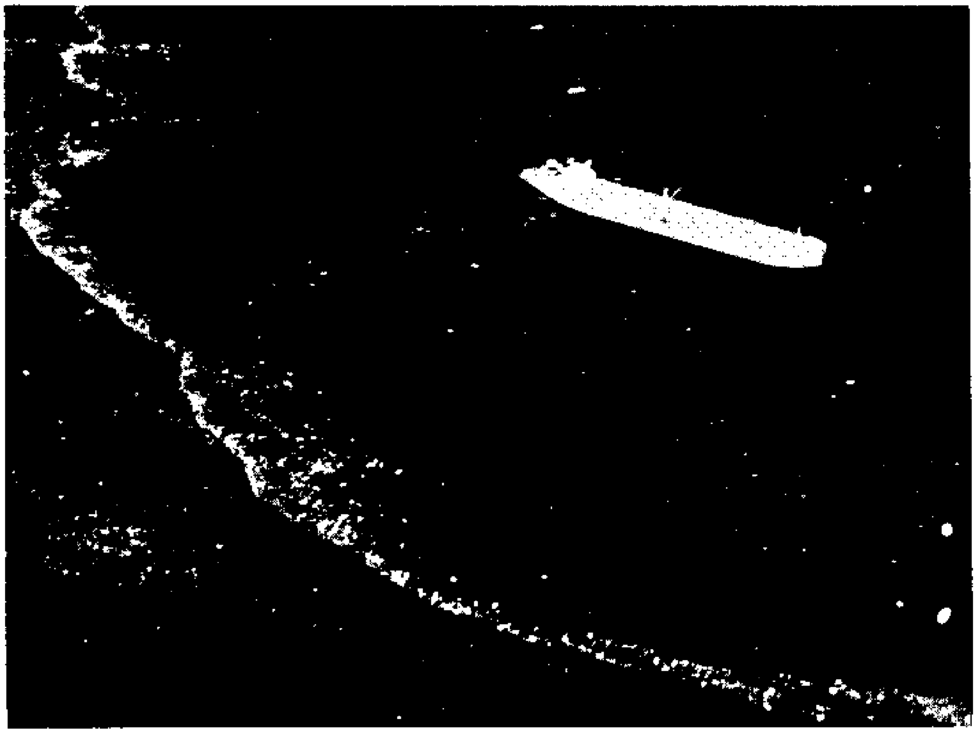
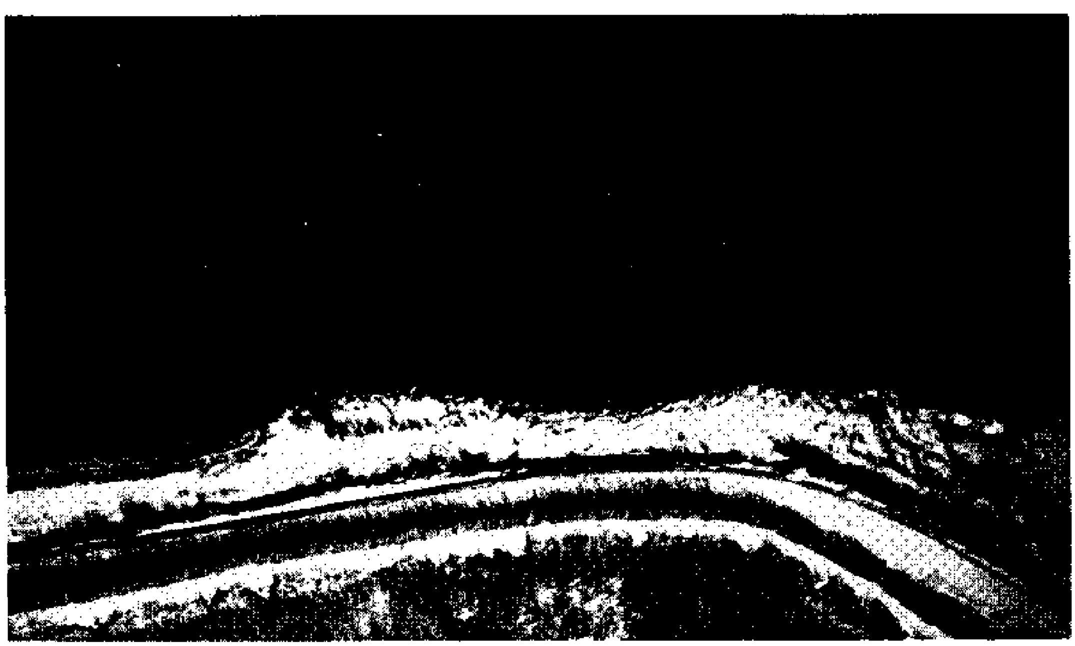


Figure 21: Small pieces of ice in streamers

Figure 22: Frost smoke on 19 January 1977



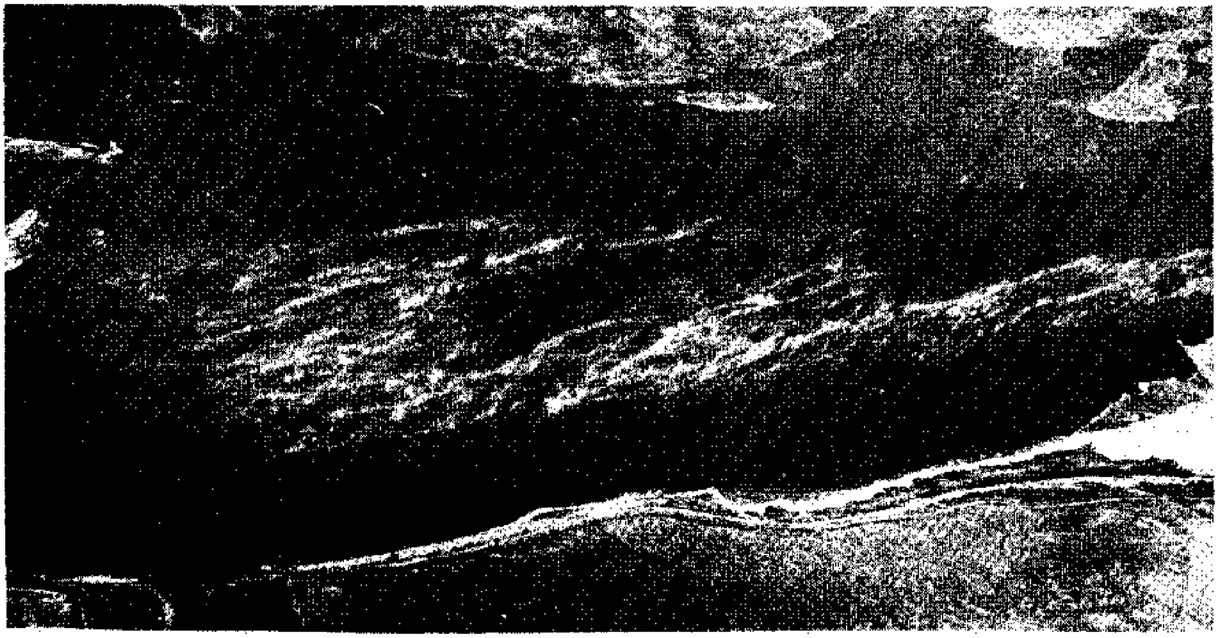


Figure 23: Frost smoke on 7 February 1977

Figure 24. Large piece of drift ice with thrust lines and slush along the windward side

Figure 25: Thaw holes in fast ice

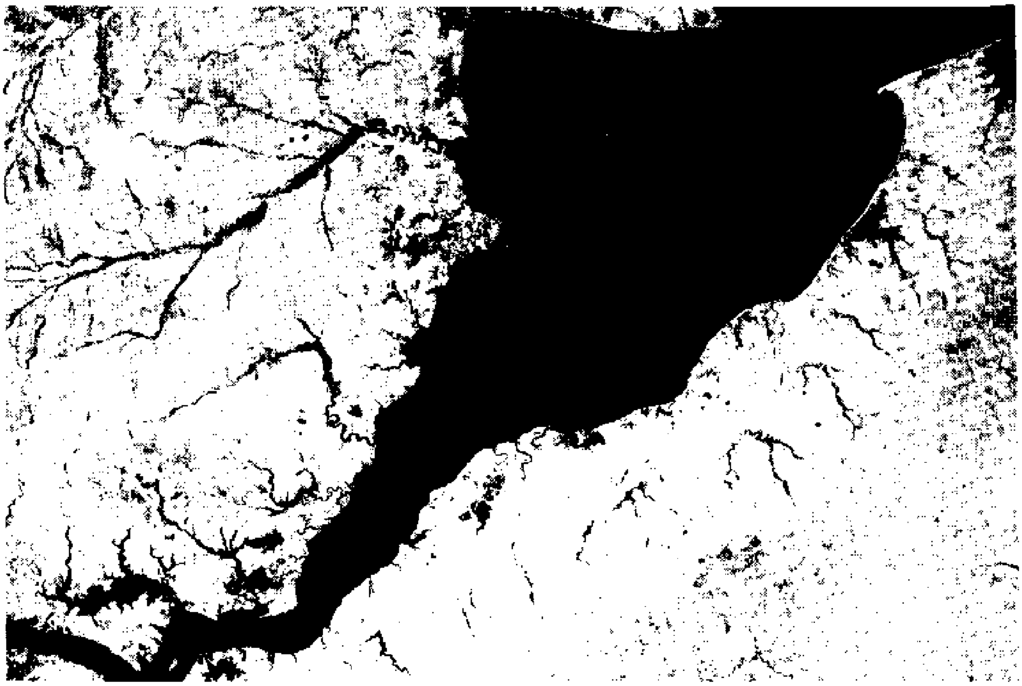


Figure 26: Band 4 Landsat image of 13 February 1973 (I.D. No. 1205-15191)

Figure 27: Band 7 Landsat image of 13 February 1973 showing ice around Cape Henlopen

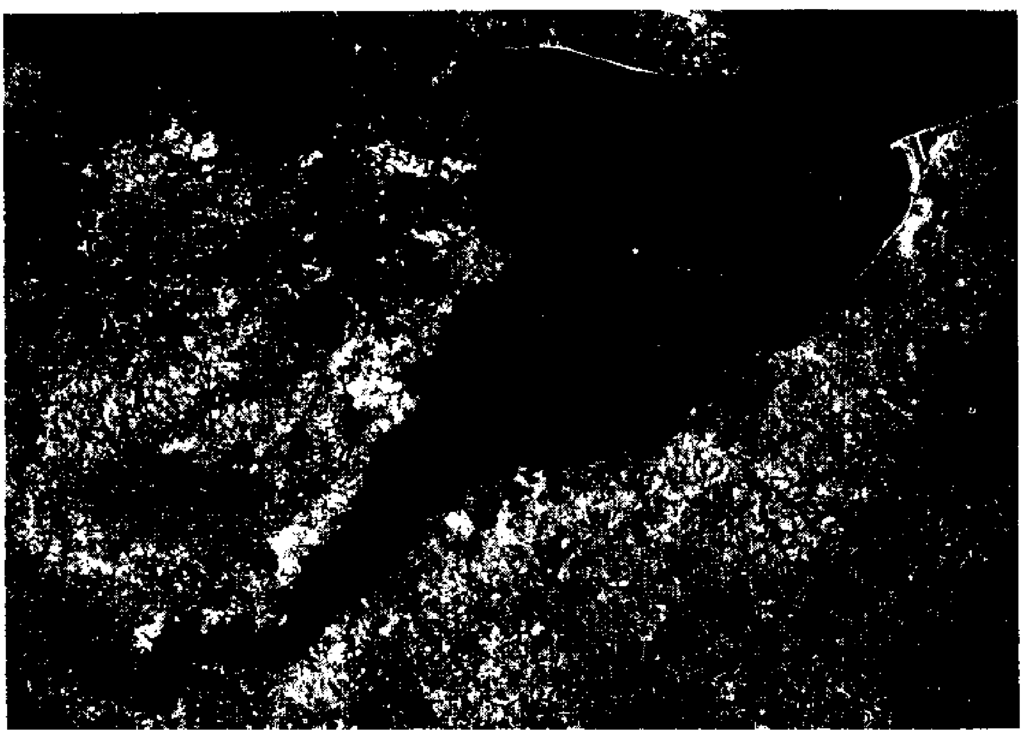
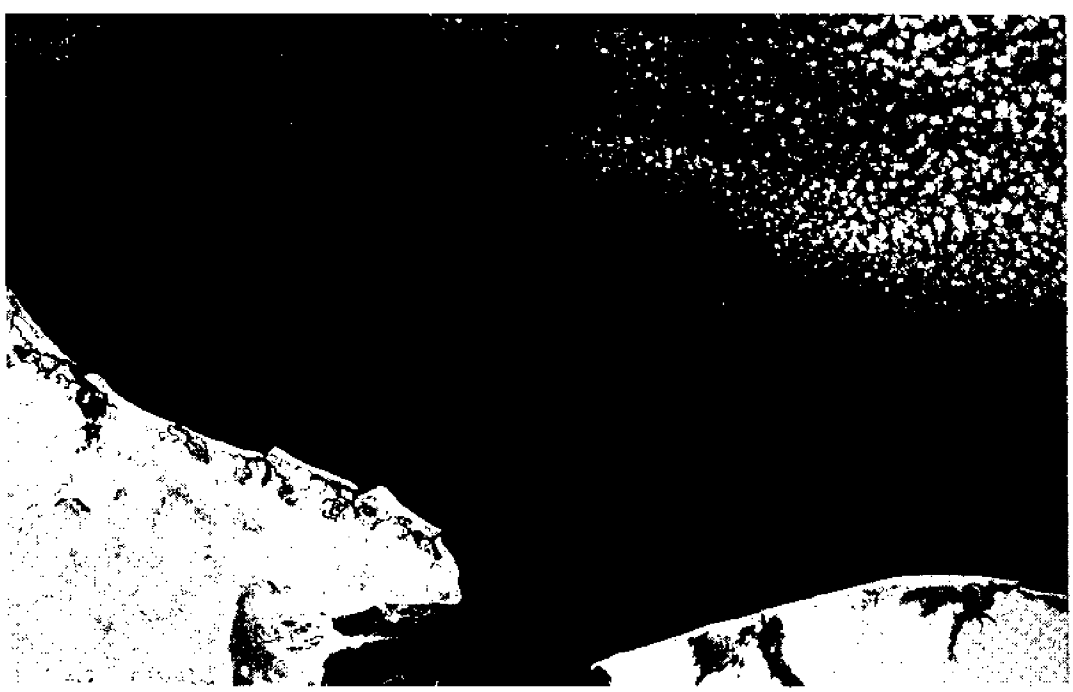


Figure 28: Band 4 Landsat image of 19 January 1976 (I.D. No. 2362-14540) showing ice north of Cape May

Figure 29: Band 5 of 19 January 1976

Figure 30: Band 6 of 19 January 1976

Figure 31: Band 7 of 19 January 1976



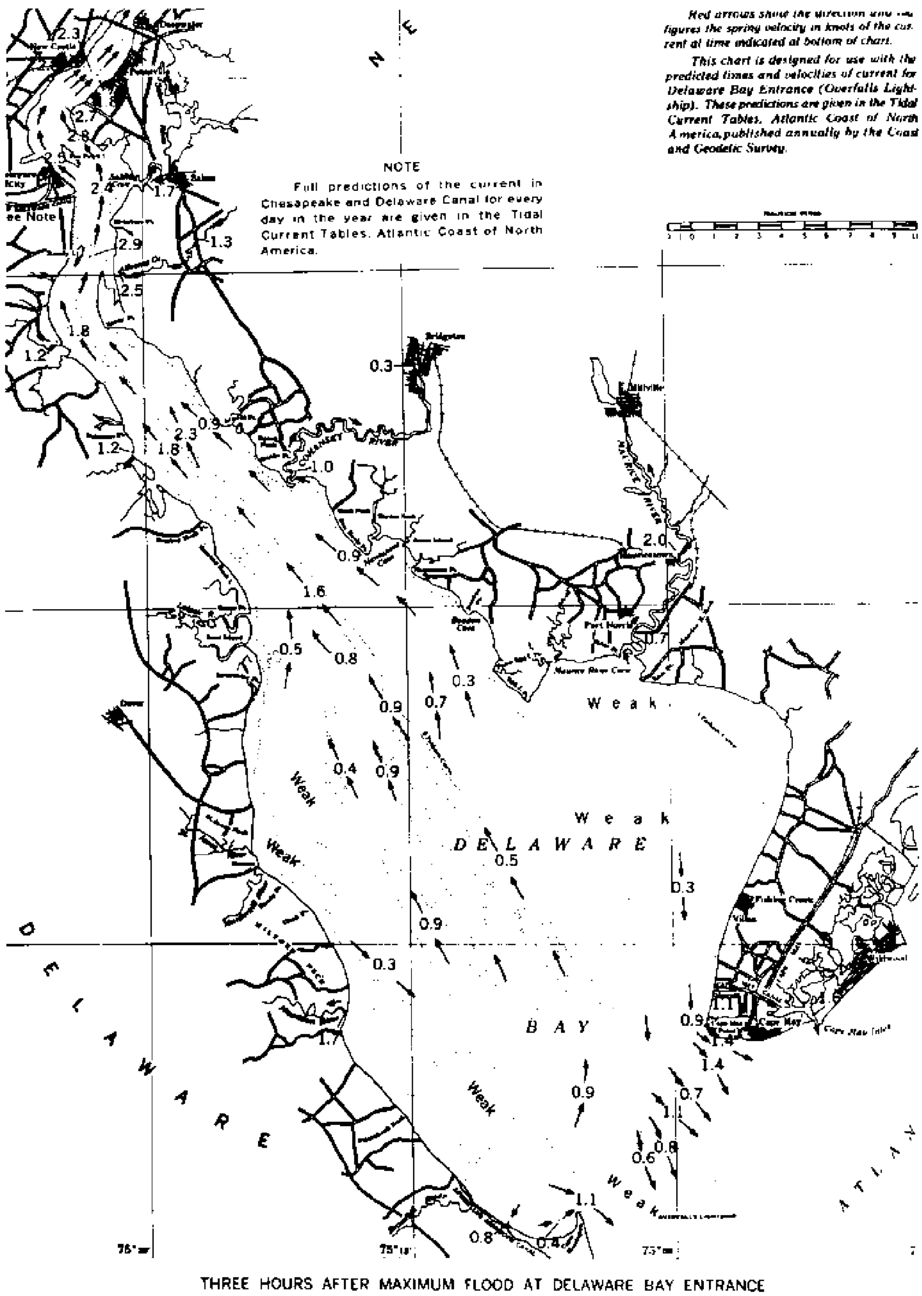


Figure 32: Tidal stage at time of image on 19 January 1976