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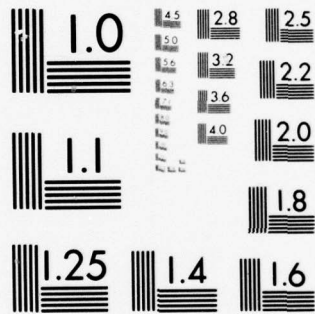
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VESSEL TRAFFIC DATA

Delaware Bay Area

L. Buhler, J. Staley, T. Nightengale, P. Walcott



FEBRUARY 1976

FINAL REPORT



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<p>16. Abstract This report presents data concerning vessel traffic in the Delaware Bay Area. The data was obtained from films of a radar PPI at two sites in the Delaware Bay Area. Also, tapes of communications activity on Channel 13 of the VHF/FM Maritime Mobile Band provided data. Data analysis obtained the following: Vessel Density; Vessel Route Identification; Vessel Speed; Close Encounter; Message Activity, Channel Utilization, and Channel Efficiency.</p>		
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OPERATIONS RESEARCH, Inc.

SILVER SPRING, MARYLAND

**VESSEL TRAFFIC DATA
FOR
DELAWARE BAY AREA**

FINAL REPORT

L. BUHLER, J. STALEY, T. NIGHTENGALE, P. WALCOTT

FEBRUARY 1976

**PREPARED UNDER CONTRACT DOT-CG-31446-A, TASK 14
FOR DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
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WASHINGTON, D.C. 20590**

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The authors wish to acknowledge the contribution to the data analysis effort made by the U. S. Coast Guard R&D Center. Early in the effort it was discovered that to obtain significant amounts of communications data would require a considerable amount of time in terms of man-hours. Presented with this problem, the R&D center, in notably minimum time, developed an automated system for extracting data from communications tapes. With this system, the cost of obtaining communications data was significantly reduced. Finally, a comment on the radar films and communications tapes is in order. The films and tapes provided by the R&D center were consistently high quality, thereby easing the problem of data extraction.

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EXECUTIVE SUMMARY

This report is a final report in accordance with Contract DOT-CG-31446-A, Task 14, "VTS Statistical Data Analysis." As per the above contract, this report constitutes the fifth in a series of final reports for selected port areas in the United States.

In the report, data concerning vessel traffic in the Delaware Bay area are presented. The data were obtained using the USCG Data Collection Van at two sites in the Bay area. The Data Collection Van is equipped with a radar to monitor vessel movements and a communications receiver to monitor communications activity. Specific data contained in the report is as follows:

RADAR

- Vessel Density - A count of the vessels present at a particular time for the data collection radar site. The count is made at regular time intervals. The data is presented in the form of a histogram. Also, vessels are classified as being small, medium, large, at anchor, tugs with tow, or dredges according to the size and behavior of the radar return.
- Vessel Route Identification - A chart depicting the routes used by vessels transiting the area.
- Vessel Speed - A histogram and table of vessel speeds observed at the radar site and tabulations of associated data.
- Close Encounter - A count of vessel encounters and close encounters observed, using close encounter criteria derived in this report.

COMMUNICATIONS

- Communications Channel Message Activity - A count of the number of messages transmitted on channel 13 of the VHF/FM Maritime Mobile Band, as a function of time. The data is presented in the form of a histogram with message counts totaled in selected fifteen-minute intervals over a 24-hour period.
- Communications Channel Utilization - The percentage of time that squelch is broken on channel 13. Utilization is computed for fifteen-minute intervals over a 24-hour period so that the variation in utilization with time of day can be observed.
- Communications Channel Efficiency - A count of the number of valid and invalid messages on channel 13 of the VHF/FM Maritime Mobile Band. Valid messages are those judged to be conforming to the Bridge-to-Bridge Radiotelephone Act. Counts are totaled within fifteen-minute intervals and a histogram of the ratio of valid messages to total messages is given. The abscissa of the histogram is time of day.

The vessel traffic data presented in the report was obtained by analyzing motion pictures of a radar PPI display. Communications data was obtained by monitoring tape recordings of the communications activity on channel 13. The radar films and communications tapes were obtained by the U.S. Coast Guard Data Collection Van. In the Delaware Bay area, the van was stationed at Chesapeake and Delaware Canal and Philadelphia Naval Base.

The data obtained for these sites are given in detail in Section II of this report.

General Observations on Delaware Bay Area

Reviewing all of the Delaware Bay Area data provided in Section II certain conclusions and observations can be made. They are as follows:

1. Vessel Density

- The highest single vessel density count of the two Delaware Bay sites was 8 vessels occurring at Philadelphia Naval Base.
- A peak traffic period was defined as a time interval during which vessel density is greater than or equal to 50% of the peak value for the site, and is sustained for more than fifteen minutes. Using this definition, the following peak periods were observed:

- Chesapeake and Delaware Canal - (for radar coverage of Tuesday through Tuesday, 1-8 April 1975)
 - Tuesday - 1145-1215, 1345-1415, 1445-1500, 1530-1545, 1615-1630
 - Wednesday - 1245-1300
 - Thursday - no peak periods
 - Friday - no peak periods
 - Saturday - no peak periods
 - Sunday - 2345-2400
 - Monday - no peak periods
 - Tuesday - no peak periods

- Philadelphia Naval Base - (for radar coverage of Tuesday through Tuesday, 8-15 April 1975)
 - Tuesday - no peak periods
 - Wednesday - 0830-0900, 1130-1145, 1245-1300, 1430-1515, 2030-2100
 - Thursday - 0245-0300, 0915-0930, 1045-1115, 1200-1215, 1345-1445
 - Friday - 0745-0800, 1030-1045, 1115-1145, 1600-1615, 1845-1900
 - Saturday - 0130-0215, 1330-1345
 - Sunday - no peak periods
 - Monday - 1700-1715
 - Tuesday - 0315-0330

- Hourly patterns or cycles in traffic density are evident only to a very limited extent. The data indicates that clear-cut cycling is the exception, rather than the rule.

2. Route Identification

Vessel traffic observed at the two sites of the Delaware Bay area travelled along the Chesapeake and Delaware Canal, and the Delaware and Schuylkill Rivers. Tracing the routes followed by the vessels revealed the following:

- The numbers of vessels at the Chesapeake and Delaware Canal site display a balance in traffic flow between the river and the canal. However, when vessel type is

considered, canal traffic is seen to be dominated by medium and small vessels, while most large vessels use the river route.

- The majority of the vessels at the Philadelphia Naval Base site travelled strictly along the Delaware River, with fewer vessels utilizing the Schuylkill River. Small ships dominated both routes. Tugs with tows were scarce, and travelled only the Delaware River.

Later sections of this report give detailed information concerning the types of vessels, predominant direction of advance, and route breakdowns when applicable.

3. Vessel Speed

Observed speeds at the Delaware Bay Area had the following ranges:

- Chesapeake and Delaware Canal 4-22 knots (11.9 knot average)
- Philadelphia Naval Base 4-18 knots (11.2 knot average)

More detailed information concerning vessel speeds according to types of vessels is given in Section 1.3 of this report.

4. Close Encounters

The observed rates of close encounters are as follows:

- Chesapeake and Delaware Canal - 42 in 24 hours (1.7)
- Philadelphia Naval Base - 51 in 7 hours (7.3)

The numbers in parentheses were obtained by dividing the number of hours into the number of encounters (i.e. number of encounters per hour).

In observing close encounters, account was taken of encounters which were not "close". That is, an encounter was called a close encounter if the distance between two vessels was below a certain threshold value. This threshold value varied from site to site as a function of the radar range scale at the site and was as follows: Chesapeake and Delaware Canal - 200 yards, Philadelphia Naval Base - 150 yards. The relationship between encounters and close encounters was as follows:

- Chesapeake and Delaware Canal - 42 close encounters out of 98 total encounters (43%)
- Philadelphia Naval Base - 51 close encounters out of 82 total encounters (62%)

where the number in parenthesis represents the percentage of close to total encounters. More detailed information regarding close encounters is given in Section 1.3 of this report.

5. Message Activity

Message activity exhibited the following peak and average values for channel 13:

	<u>Day of Coverage</u>	<u>Peak No. of Messages</u>	<u>Time of Peak</u>	<u>Average No. of Messages</u>
Chesapeake and Delaware Canal	Thursday, 3 April 1975	170	0330 - 0345	62
Philadelphia Naval Base	Thursday, 10 April 1975	238	1045 - 1100	108

6. Channel Utilization

Channel 13 utilization exhibited the following peak and average percentages.

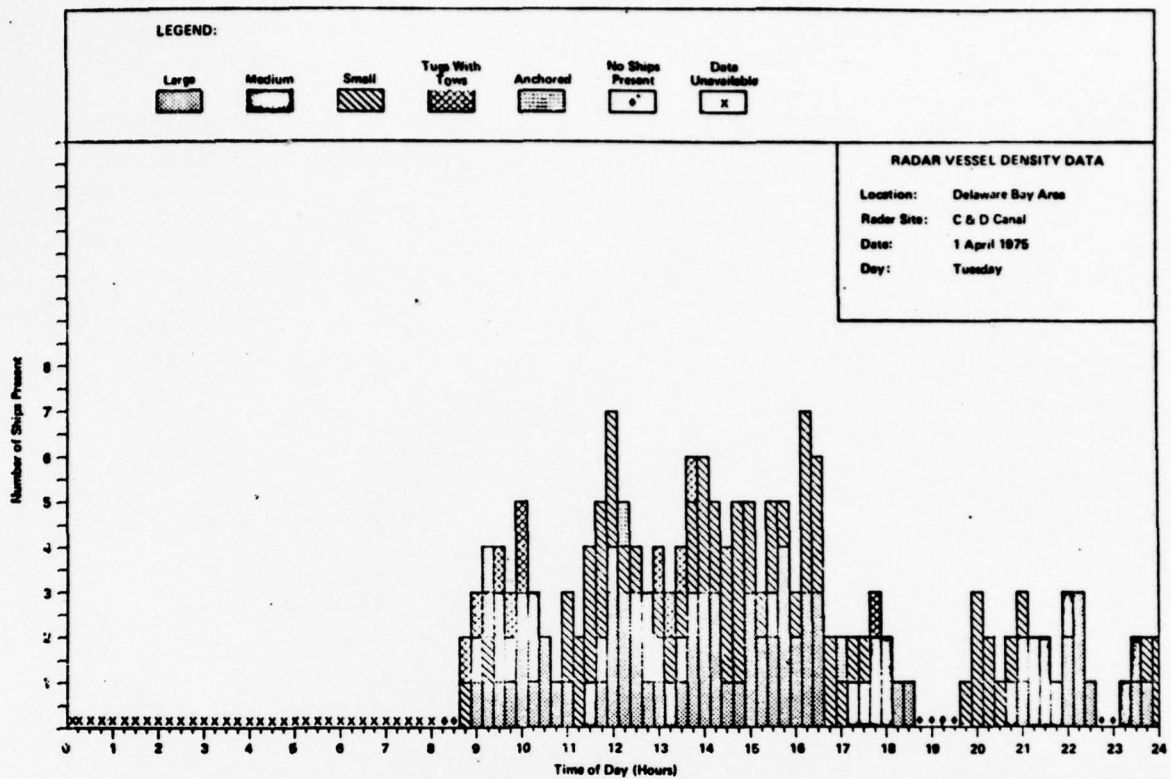
	<u>Day of Coverage</u>	<u>Peak %</u>	<u>Time of Peak</u>	<u>Average (%)</u>
Chesapeake and Delaware Canal	Thursday, 3 April 1975	39	0415 - 0430	12
Philadelphia Naval Base	Thursday, 10 April 1975	41	0930 - 0945	19

7. Channel Efficiency

Channel efficiency data are as follows:

	<u>Peak (%)</u>	<u>Average (%)</u>
Chesapeake and Delaware Canal	100	63
Philadelphia Naval Base	100	79

A sample of the form in which each of the various types of data is presented is given in Figure E-1.



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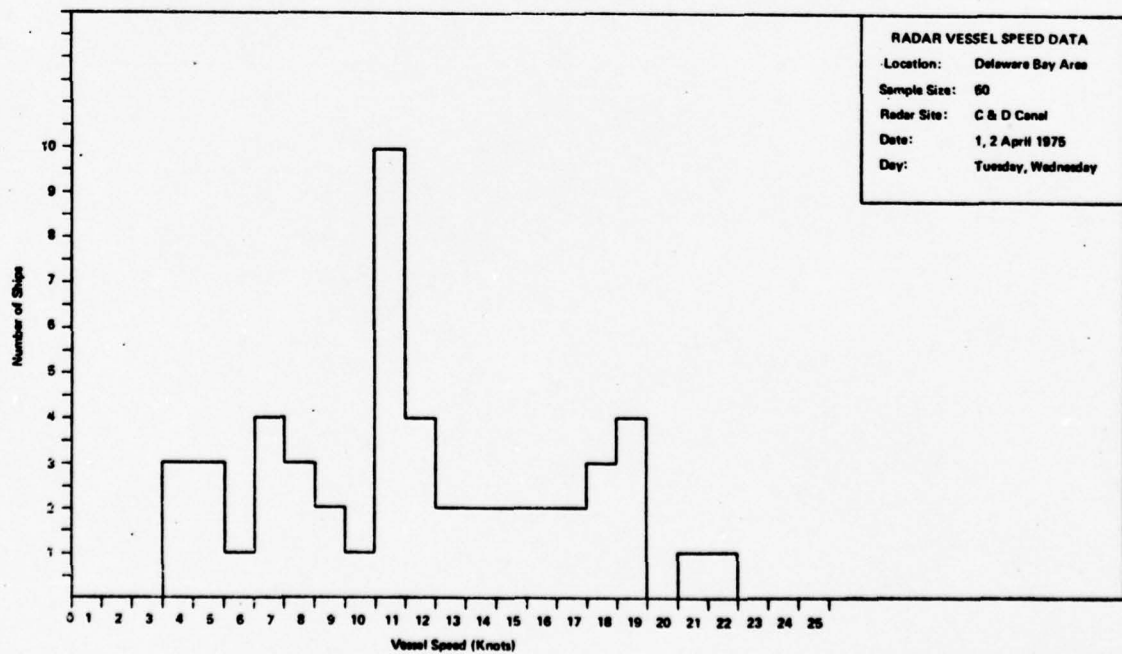


FIGURE E-2 SAMPLE DATA

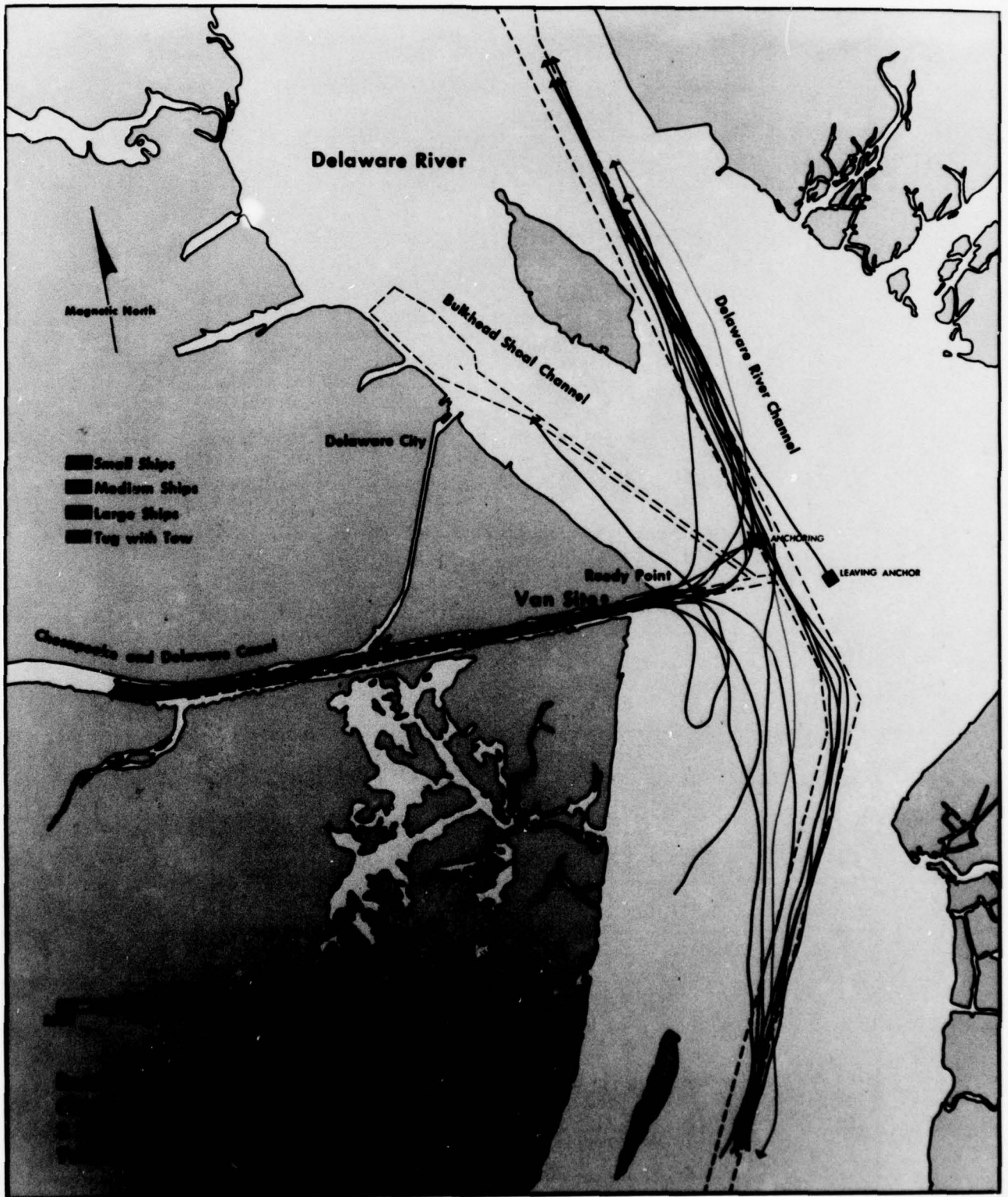
CLOSE ENCOUNTER
FOR
CHESAPEAKE AND DELAWARE CANAL

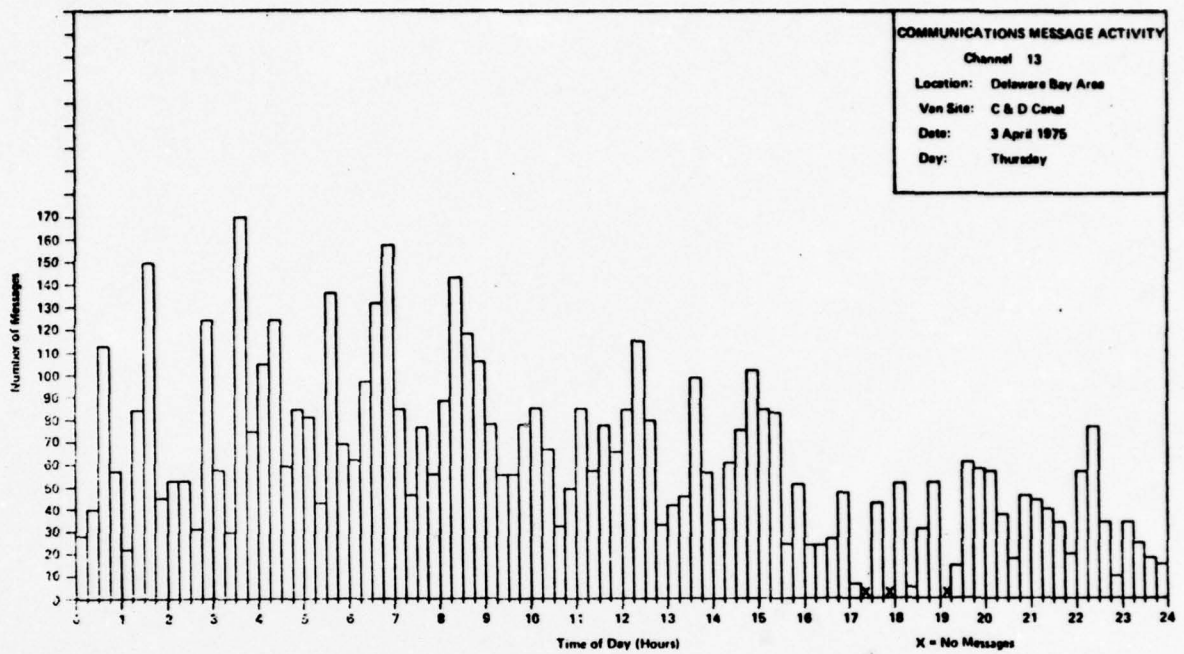
SPEED DATA
FOR
CHESAPEAKE AND DELAWARE CANAL

No.	Day	Time Hour/Minute	Distance Yards	Size	Manner of Approach*	Vessel No.	Vessel Size	Average Speed in Knots	Direction	Day	Time Hour/Minute
1	Tuesday 1 April 1975	09 00	120	1 large, 1 small	0	1	large	12	N	Tuesday 1 April 1975	08 41
2		09 52	195	1 tug, 1 large	P	2	large	4	N		08 43
3		10 46	<38	1 medium, 1 small	P	3	small	16	N		08 56
4		11 31	<50	1 large, 1 small	P	4	small	14	E		09 04
5		11 32	<75	1 large, 1 medium	P	5	tug	10	N		09 26
6		11 35	<38	1 medium, 1 small	0	6	large	11	E		09 36
7		11 43	<30	1 medium, 1 small	P	7	tug	13	S		09 50
8		11 47	<38	1 medium, 1 small	P	8	large	12	N		09 59
9		11 56	<30	2 small	P	9	large	17	N		10 29
10		12 33	200	1 large, 1 medium	0	10	medium	22	S		10 58
11		12 45	180	2 medium	C	11	large	11	E		11 25
12		12 52	95	1 large, 1 small	0	12	small	18	S		11 33
13		13 38	75	1 large, 1 small	P	13	large	6	N		11 41
14		13 44	75	1 large, 1 small	P	14	large	15	N		12 14
15		13 54	195	1 large, 1 small	C	15	medium	4	W		12 22
16		13 57	165	1 large, 1 medium	P	16	medium	12	S		12 41
17		13 57	115	2 large	P	17	large	7	NW		12 50
18		14 09	175	1 large, 1 medium	P	18	medium	11	S		12 54
19		14 13	150	2 large	0	19	tug	8	S		12 55
20		14 14	170	2 large	P	20	large	4	S		13 24
21		14 15	100	2 large	P	21	large	19	N		13 24
22		14 41	<25	2 small	P	22	large	18	N		13 42
23		14 42	<25	2 small	P	23	small	11	E		14 28
24		14 44	<45	2 small	P	24	small	21	NW		14 40
25		14 58	140	2 large	P	25	medium	19	W		14 47
26	Tuesday 1 April 1975	15 18	100	1 large, 1 small	0	26	small	5	S		14 55
27		15 20	140	2 large	P	27	medium	11	SE	Tuesday 1 April 1975	15 24

*P = Passing
0 = Overtaking
C = Crossing
< = Less than

FIGURE E-2 SAMPLE DATA (Cont.)





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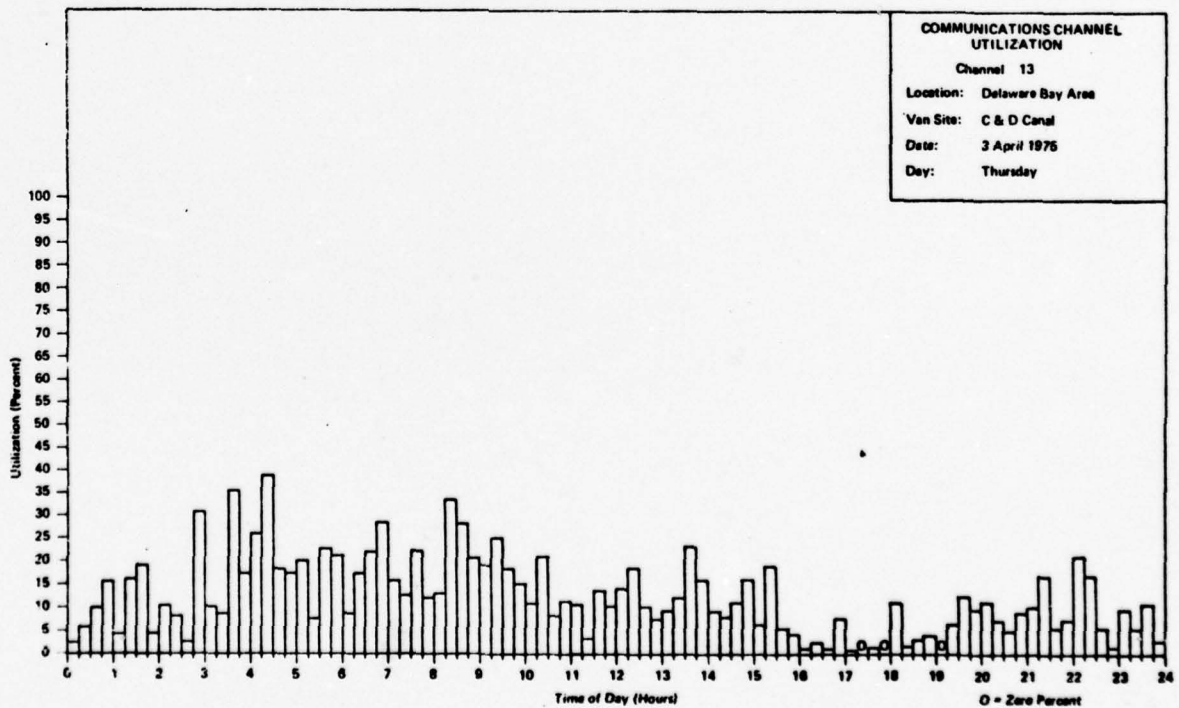


FIGURE E-2 SAMPLE DATA (Cont.)

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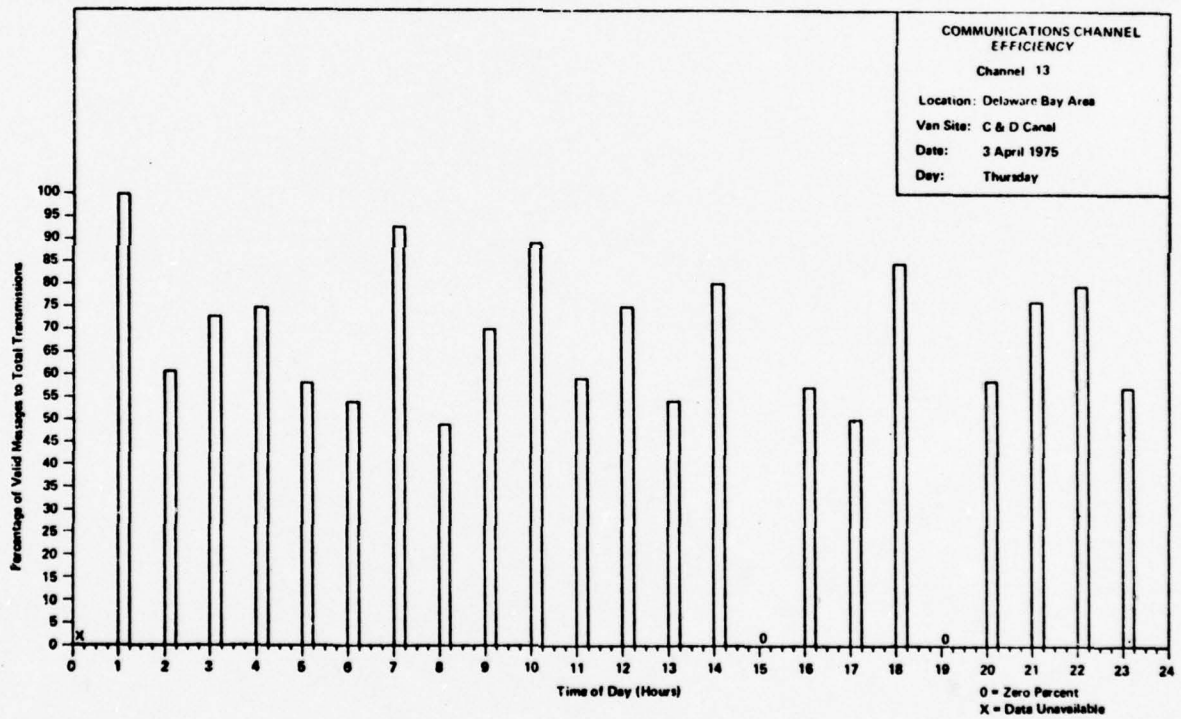


FIGURE E-2 SAMPLE DATA (Cont.)

I. DISCUSSION OF DATA

1.1 CHESAPEAKE AND DELAWARE CANAL SITE

The 19 mile Chesapeake and Delaware (C&D) Canal runs east and west, connecting the head of the Chesapeake Bay with the Delaware River. It provides a link in the shipping route of protected waters from Philadelphia to Baltimore and on to the Hampton-Newport News area. At the eastern (Delaware River) entrance of the canal, the northern bank ends with a jetty at Reedy Point. The radar van was situated here, a few yards north of the canal and west of the jetty, with the radar equipment adjusted to a return radius of 3 nm. The coverage area thus included 3 nm of the canal and 6 nm of the river.

The main channel of the river is the Delaware River channel, which passes the canal entrance and continues on north to Philadelphia with a dredged depth of 40 ft. As it passes the canal entrance, a small channel - Bulkhead Shoal Channel, which is maintained by Getty Oil Company - branches off heading northwest to Delaware City. As expected, most river traffic employs the main river channel. The route identification for this site, with data taken from 0915 to 1215 Tuesday, April 1975, shows that even during peak traffic periods, this channel holds the bulk of river traffic. Viewing the traffic pattern displayed on this chart as having three branches (the canal, the river from the canal north, and the river from the canal south) similarity in traffic flow within each of the three is observed. During this 3 hour period, the segment from the canal north was transited by 10 vessels, from the canal south by 9 vessels, and the canal itself by 10 vessels.

When data for this site were taken with respect to vessel type, they were assigned to categories of large, medium, small, tug with tow, and anchored. It should be kept in mind when reviewing this data, however, that since it is a practice of tug companies of the area to push barges, rather than to pull them in tow, the large and medium categories may include tugs with barges which appeared on radar as single returns. The vessel type

designation scheme of the route identification chart shows river traffic to be dominated by large vessels, while medium and small vessels are predominant in the canal. The minimal presence of large vessels in the canal is due at least in part to the length and depth constrictions of the canal. The maximum length is set at 725 ft. by regulation, and although the maximum project depth is 35 ft., the present maximum depth is as small as 25 ft. in some areas, due to local government restrictions on canal dredging practice. The preference which medium and small vessels show for the canal is not influenced by such physical or regulatory restrictions.

The vessel density data, taken for the week of 0815 Tuesday through 0815 Tuesday, 1 - 8 April 1975, show neither daily nor weekly cycles. The maximum number of vessels present is seven, and is obtained only twice - at 1145 and 1615 Tuesday. Peak periods of more than half the maximum are sustained for more than half an hour on four occasions at the seemingly erratic time periods of: 1130 to 1230 and 1330 to 1500 Tuesday; 1245 to 1330 Wednesday; and 2330 Sunday to 0015 Monday. Twenty-seven percent of the sample period showed no ships present, and only 8% showed more than three ships present. Low vessel density is the norm for this site - too low perhaps to provide a data base sufficient to determine cycles.

The speeds of the 50 vessels clocked fall between 4 and 22 knots, with a median of 13 knots, a mean of 12 knots, and 20% at 11 knots. During a 24 hour period of observation, close encounters (those of less than 200 yards) occurred at a rate of 6 per hour, or 0.4 close encounters per encounter.

Communications data, taken for Thursday, 3 April 1975, show a strong positive correlation between message activity and channel utilization, with 81% of the periods sampled displaying a direct relationship. Channel utilization and message activity show a tendency toward a positive correlation with channel efficiency, as the sample periods show direct relationships over 58% and 64% of the samples respectively. The average channel utilization of 12.26% is certainly no lower than would be expected on a day of below average vessel density, at a site where the average itself is low. The fact that there is an average of 10.33% utilization during those intervals which were sampled at zero vessel density indicates that the radio coverage exceeds the radar coverage.

1.2 PHILADELPHIA NAVAL BASE SITE

Along the Delaware River, northeast from the Chesapeake and Delaware Canal is located the Philadelphia Naval Base. It lies near the junction of the Delaware and Schuylkill Rivers at Philadelphia, Pennsylvania, and extends east along the Delaware River for about 2.7 nm. It is a part of the port of Philadelphia which is one of the chief ports of the United States. In defining this for customs purposes, the U.S. Coast Pilot 3 Atlantic Coast Handbook, states that it..."comprises such waters of the Delaware and Schuylkill Rivers bordering on the municipality as are navigable; the municipal limits on Delaware River extend from Fort Mifflin on the south to Poguessing Creek on the north, a distance of about 20 miles."

The radar van was situated on the end of pier 4 of the Base. This is approximately .72 nm from the junction of the Delaware and Schuylkill Rivers. The radar equipment on the van was set to a return radius of 1.5 nm. This return radius covered approximately 213⁰, rotating northwest to south, to slightly northeast of the van. This area includes 1.5 nm of the Delaware River, west (from Ft. Mifflin), and east (to Horseshoe Bend) of the van. It covers the entrance into the Schuylkill River. New Jersey is northeast and south of the van.

The United States Coast Pilot 3 Atlantic Coast Handbook defines the activity at the Port of Philadelphia as follows: "Large quantities of general cargo are handled at the port in both foreign and domestic trade. In addition, crude petroleum and petroleum products, sugar and ore are imported, while coal, grain, and refined petroleum products are exported. Coastwise receipts are mostly crude petroleum and petroleum products and shipments consist chiefly of refined petroleum products. Philadelphia has over 45 deep water piers and wharves along its Delaware River waterfront and along Schuylkill River. The piers and wharves generally have highway and railroad connections. Most of the general cargo piers and wharves are between the Walt Whitman Bridge and Port Richmond, 2 miles above the Benjamin Franklin Bridge and at Ten Mile Point, 7 miles above the Benjamin Franklin Bridge. The Schuylkill River wharves and piers are mostly used to handle bulk petroleum products."

The area covered by the radar does not include the area where most of the piers are (above the Walt Whitman Bridge), instead the return shows the traffic entering and leaving the large pier and wharf area along the Delaware and the Schuylkill Rivers. In this coverage area exists an oil refinery approximately .75 nm southeast of the van, and a ferry route crossing the Delaware River from New Jersey (south) to Pennsylvania (east of the van).

The route identification was observed for Wednesday, 9 April 1975 from 0601 to 1045 hours. Major traffic patterns observed were vessels going up or down the Delaware River, vessels entering or exiting the Schuylkill River, and the ferry route.

The following table illustrates the use of each possible route at this site. The percentages are the result of dividing the number of vessels present on each route by the total number of vessels present (44).

Route	Directions	
	Upriver	Downriver
Delaware River	21%	27%
Delaware River to the Schuylkill River	11%	11%
Schuylkill River to the Delaware River	2%	9%
	34%	47%

18% of the vessels utilized the Ferry route.

Of the total 44 vessels present at this site, 66% were small, 16% were medium, 14% were large, and 5% were tugs with tows.

The following was also derived from the route identification chart:

Route	Percentages Within Each Route			
	Small	Medium	Large	Tug with Tow
Delaware River	48%	24%	19%	10%
Entering Schuylkill River	80%	10%	10%	0%
Leaving Schuylkill River	60%	20%	20%	0%

During the time period that the route identification was observed, the ferry crossed over between 0645 - 0802 hours, at an approximate rate of 4 crossings per hour. All vessels leaving the area surrounding the oil refinery headed down the Delaware River, while all the vessels approaching this area were heading up the Delaware River.

The U.S. Coast Pilot 3 Atlantic Coast Handbook further states that: "As a general rule, tugs are not required for vessels moving between Philadelphia and the sea; most vessels traverse this distance under their own power. Cargo is generally handled by ships' tackle; special handling equipment...a floating derrick with a 125-ton capacity is available." Arrangements can also be made for the use of the 350-ton hammerhead crane situated on pier 4 of the Philadelphia Naval Base. The preceding is a possible explanation for the presence of a small number of tugs with tows within the radar coverage area. Though not observed in the period radar vessel density data was taken, the derrick and crane could influence vessel behavior when cargo-bearing vessels approach and leave these two facilities. Traffic within the radar coverage area can be considered as passing through the site.

The vessel density data covered from 1445, 8 April 1975 to 1430, 15 April 1975 - Tuesday to Tuesday respectively. There is no daily traffic pattern similarity throughout the week. The average numbers of vessels slowly decrease from Tuesday through Sunday, and then start increasing on Monday.

Close encounter data was recorded from 0811 to 1821 on 9 April 1975. During this time period there were 51 close encounters of less than 150 yards, out of 82 total encounters. There were also three peak traffic periods during this time period. The following are the number of close encounters occurring within seven minutes before and after each high peak traffic period, along with the number of moving vessels present during the peak time: 0823 - 0837, 5 close encounters occurred with 8 vessels present, 1123 - 1137, 4 close encounters occurred with 7 vessels present, and during 1508 - 1522, 6 close encounters occurred with 8 vessels present. The maximum number of vessels present at one count during the eight days of coverage was 8.

The speed data for this site was observed during 1533 to 1016 hours of 8 - 9 April 1975, Tuesday and Wednesday. Of the 50 vessels observed 40% were medium, 28% large, 16% were small and 16% were tugs. Small vessels averaged 12.1 knots, medium vessels averaged 11.6 knots, large vessels averaged 11.4 knots and tugs with tows averaged 8.9 knots.

Communications data were taken for Thursday, 10 April 1975, a day of average vessel traffic. The data displays a positive relationship between channel utilization and message activity. Comparing these values over time shows a direct proportion over 79% of the intervals, with 52% of these intervals simultaneously increasing and 48% simultaneously decreasing. Channel utilization shows a positive relationship to channel efficiency 57% of the time, while message activity shows a negative relationship to channel efficiency 57% of the time.

The average utilization percentage for 10 April 1975 was 18.7%; this means that, on the average, for every 15 minutes, 2.8 minutes were utilized. Meanwhile, the average number of vessels present that day was 3, so the low average utilization percentage is justifiable.

1.3 DETAILED DATA SUMMARY

The following observations can be made on the data collected for the two sites in the Delaware Bay area.

1. Vessel Density

- A peak traffic period is defined as a time interval during which vessel density is within 50% of the peak value for the site, and is sustained for more than 15 minutes. A lack of peak periods indicates relatively uniform traffic activity throughout the day.

Based on this definition of a peak period, these observations were made:

- Chesapeake and Delaware Canal - the first day of vessel density data taken for this site had the longest sustained and the greatest number of peak periods. The longest sustained was from 1330-1515, the others were... 0915-0945; 1130-1245; and 1615-1645. During the seven days following, a total of eight peak periods were observed. There was no consistency in the times of their occurrence, but one noteworthy phenomenon is that the mean duration of these eight peak periods was 30 minutes.
- Philadelphia Naval Base - for the eight-day vessel density coverage here, there was a total of 39 peak periods. They occurred mainly in the range 0800-1130, and around 1300. While 39 peak periods make an average of 5 per day, three days, Wednesday thru Friday accounted for 27 of those 39; an average of 9 per day or 70% of the total number of peak periods.

2. Route Identification

The following definitions will apply to all route identification charts: A tug with tow is a small vessel pulling one or more other vessels. Small, medium, and large ships are so defined in a comparative relationship. A small ship is further delineated as it is never larger than the small, pulling vessel referred to in the tug with tow definition.

The route identification charts referred to in Section II. indicate the following:

- Chesapeake and Delaware Canal
(coverage - 0915-1215, 1 April 1975)

<u>Type of Vessel</u>	<u>No. of Vessels Present</u>	<u>Route and Direction</u>
Small Ship	4	Chesapeake and Delaware Canal, West
	1	Bulkhead Shoal Channel, Northeast
	1	Delaware River Channel, North
Medium Ship	2	Chesapeake and Delaware Canal, East
	1	Delaware River Channel, North
Large Ship	1	Chesapeake and Delaware Canal, West
	6	Delaware River Channel, North
Tug with Tow	1	Delaware River Channel, South
Total No. of Vessels	17	

There are three channels: Delaware River Channel, Chesapeake and Delaware Canal (C&D Canal), and Bulkhead Shoal Channel. Delaware River Channel had eight ships going North and one going South. The C&D Canal had five ships travelling west and two east. Only one ship was observed in Bulkhead Shoal Channel in the time period covered. The C&D Canal and Delaware River Channel had similar traffic volumes but large ships were more common to the Delaware River Channel while C&D Canal had greater small and medium ship traffic. In a combination of large ships and tugs with tows to form one category, and small and medium ships combining to form the second, the following ratios were derived:

- Delaware River Channel - 7 (tug with tow + large) to 2 (small + medium)
- Chesapeake and Delaware Canal - 6 (small + medium) to 1 (tug with tow + large)

● Philadelphia Naval Base (coverage 0601-1045, 9 April 1975)

<u>Type of Vessel</u>	<u>No. of Vessels Present</u>	<u>Rivers Traveled and Direction</u>
Small Ships	6	Delaware, Downriver
	4	Delaware to Schuylkill, Downriver
	2	Schuylkill to Delaware, Downriver
	4	Delaware, Upriver
	4	Delaware to Schuylkill, Upriver
	1	Schuylkill to Delaware, Upriver
Medium Ships	8	Ferry Route - Delaware, Crossing
	4	Delaware, Downriver
	1	Delaware to Schuylkill, Downriver
	1	Schuylkill to Delaware, Downriver
Large Ships	1	Delaware, Upriver
	1	Schuylkill to Delaware, Downriver
	3	Delaware, Downriver
	1	Delaware, Upriver

<u>Type of Vessel</u>	<u>No. of Vessels Present</u>	<u>Rivers Travelled and Direction</u>
Tug with Tow	1	Delaware, Downriver
	1	Delaware, Upriver
Total No. of Vessels	44	

The bulk of traffic at this site strictly utilizes the Delaware River, while the Schuylkill River carries the remainder, (about a quarter of the total traffic volume). The route identification chart shows 29 small ships, 7 medium ships, 6 large ships and 2 tugs with tow at this site. There were 21 vessels travelling only on the Delaware River, 10 vessels entering the Schuylkill River from the Delaware River, and 5 vessels leaving the Schuylkill River from the Delaware River. The number, type, and direction of vessels utilizing each river is presented in the following way:

<u>Route</u>	<u>Upriver</u>	<u>Downriver</u>
Delaware River	4 small ships 1 medium ship 3 large ships 1 tug with tow	6 small ships 4 medium ships 1 large ship 1 tug with tow
Delaware River to Schuylkill River	4 small ships 1 large ship	4 small ships 1 medium ship
Schuylkill River to Delaware River	1 small ship	2 small ships 1 medium ship 1 large ship

There were 8 small ships utilizing the Ferry route.

There were a total of 44 vessels observed at this site. Excluding the count of 8 vessels using the Ferry route, 42% of the 36 vessels travelled upriver, and 58% travelled downriver. Of the 42% travelling upriver the following applies:

- 60% were small ships
- 7% were medium ships
- 27% were large ships
- 7% were tugs with tow

Of the 58% travelling downriver the following applies:

- 57% were small ships
- 29% were medium ships
- 20% were large ships
- 5% were tugs with tow

3. Vessel Speed

Observed speeds in the Delaware Bay Area had the following ranges:

- Chesapeake and Delaware Canal 4 - 22 knots (11.9 knot average)
- Philadelphia Naval Base 4 - 18 knots (11.2 knot average)

The following data represents the fastest, slowest, and average speed (in knots) for each vessel-type, and for each site.

- Chesapeake and Delaware Canal (26 hour coverage between 1 and 2 April, 1975)

<u>Type of Vessel</u>	<u>No. of Vessels</u>			
	<u>Present</u>	<u>Fastest</u>	<u>Slowest</u>	<u>Average</u>
Small ship	8	21	5	14.0
Medium ship	16	22	4	10.3
Large ship	21	19	4	12.9
Tug with Tow	<u>5</u>	13	5	9.4
Total	50			

- Philadelphia Naval Base (19 hour coverage between 8 and 9 April, 1975)

<u>Type of Vessel</u>	<u>No. of Vessels</u>			
	<u>Present</u>	<u>Fastest</u>	<u>Slowest</u>	<u>Average</u>
Small ship	8	17	8	12.1
Medium ship	20	15	7	11.6
Large ship	14	18	4	11.4
Tug with Tow	<u>8</u>	11	5	8.9
Total	50			

The following data presents the different speeds for each type of vessel, at each site:

<u>Small Ships at:</u>	<u>No. of Vessels</u>			
	<u>Present</u>	<u>Fastest</u>	<u>Slowest</u>	<u>Average</u>
Chesapeake and Delaware Canal	8	21	5	14.0
Philadelphia Naval Base	8	<u>17</u>	<u>8</u>	<u>12.1</u>
	Average	19	6.5	13.1

<u>Medium Ships at:</u>	<u>No. of Vessels</u>			
	<u>Present</u>	<u>Fastest</u>	<u>Slowest</u>	<u>Average</u>
Chesapeake and Delaware Canal	16	22	4	10.3
Philadelphia Naval Base	20	15	7	11.6
	Average	18.5	5.5	11

<u>Large Ships at:</u>	<u>No. of Vessels</u>			
	<u>Present</u>	<u>Fastest</u>	<u>Slowest</u>	<u>Average</u>
Chesapeake and Delaware Canal	21	19	4	12.9
Philadelphia Naval Base	14	18	4	11.4
	Average	18.5	4	12.2

<u>Tugs with Tow at:</u>	<u>No. of Vessels</u>			
	<u>Present</u>	<u>Fastest</u>	<u>Slowest</u>	<u>Average</u>
Chesapeake and Delaware Canal	5	13	5	9.4
Philadelphia Naval Base	8	11	5	8.9
	Average	12	5	9.2

4. Close Encounters

The observed rates of close encounters are as follows:

Chesapeake and Delaware Canal	42 in 24 hours (1.8) out of 98 total encounters
Philadelphia Naval Base	51 in 7 hours (7.3) out of 82 total encounters

The numbers in parentheses were obtained by dividing the number of hours into the number of close encounters (i.e. the number of close encounters per hour). The ratio of close encounters per hour between Philadelphia Naval Base and Chesapeake and Delaware Canal is 4 to 1. Below, the close encounters observed are categorized in vessel-type combinations, the total number of encounters observed involving each combination, and their range in yards. The manner of approach is also given (P = Passing, O = Overtaking, C = Crossing). Radar resolution limits the accuracy of measured distances.

● Chesapeake and Delaware Canal (24 hour coverage)

No. & Manner of Approach			Type of Vessel Combination	No. of Combinations Observed	Range of Close Encounters (Yards)
P	O	C			
7	-	-	2 small ships	7	< 25 - 100
-	-	1	2 medium ships	1	180
10	1	-	2 large ships	11	95 - 175
3	2	-	1 small ship and 1 medium ship	5	< 30 - 80
5	3	1	1 small ship and 1 large ship	9	< 50 - 195
6	1	-	1 medium ship and 1 large ship	7	< 75 - 200
1	-	-	1 medium ship and 1 tug	1	125
<u>1</u>	<u>-</u>	<u>-</u>	1 large ship and 1 tug	<u>1</u>	< 38
33	7	2	Totals	42	

● Philadelphia Naval Base (7 hour coverage)

No. & Manner of Approach			Type of Vessel Combination	No. of Combinations Observed	Range of Close Encounters (Yards)
P	O	C			
3	-	-	2 small ships	3	50 - 122
9	2	-	2 medium ships	11	55 - 140
2	1	-	2 large ships	3	100 - 125
6	6	1	1 small ship and 1 medium ship	13	48 - 120
11	1	-	1 small ship and 1 large ship	12	75 - 135
2	1	-	1 small ship and 1 tug	3	110 - 125
3	-	-	1 medium ship and 1 large ship	3	60 - 75
<u>1</u>	<u>2</u>	<u>-</u>	1 large ship and 1 tug	<u>3</u>	< 25 - 135
37	13	1	Totals	51	

5. Message Activity

Message activity exhibited the following peak and average values for channel 13:

	Day of Coverage	Peak No. of	Time of Peak	Average No.
		Messages		of Messages
Chesapeake and Delaware Canal	Thursday, 3 April 1975	170	0330 - 0345	62
Philadelphia Naval Base	Thursday, 10 April 1975	238	1045 - 1100	108

6. Channel Utilization

Channel 13 utilization exhibited the following peak and average percentages:

	<u>Day of Coverage</u>	<u>Peak (%)</u>	<u>Time of Peak</u>	<u>Average (%)</u>
Chesapeake and Delaware Canal	Thursday, 3 April 1975	39	0415 - 0430	12
Philadelphia Naval Base	Thursday, 10 April 1975	41	0930 - 0945	19

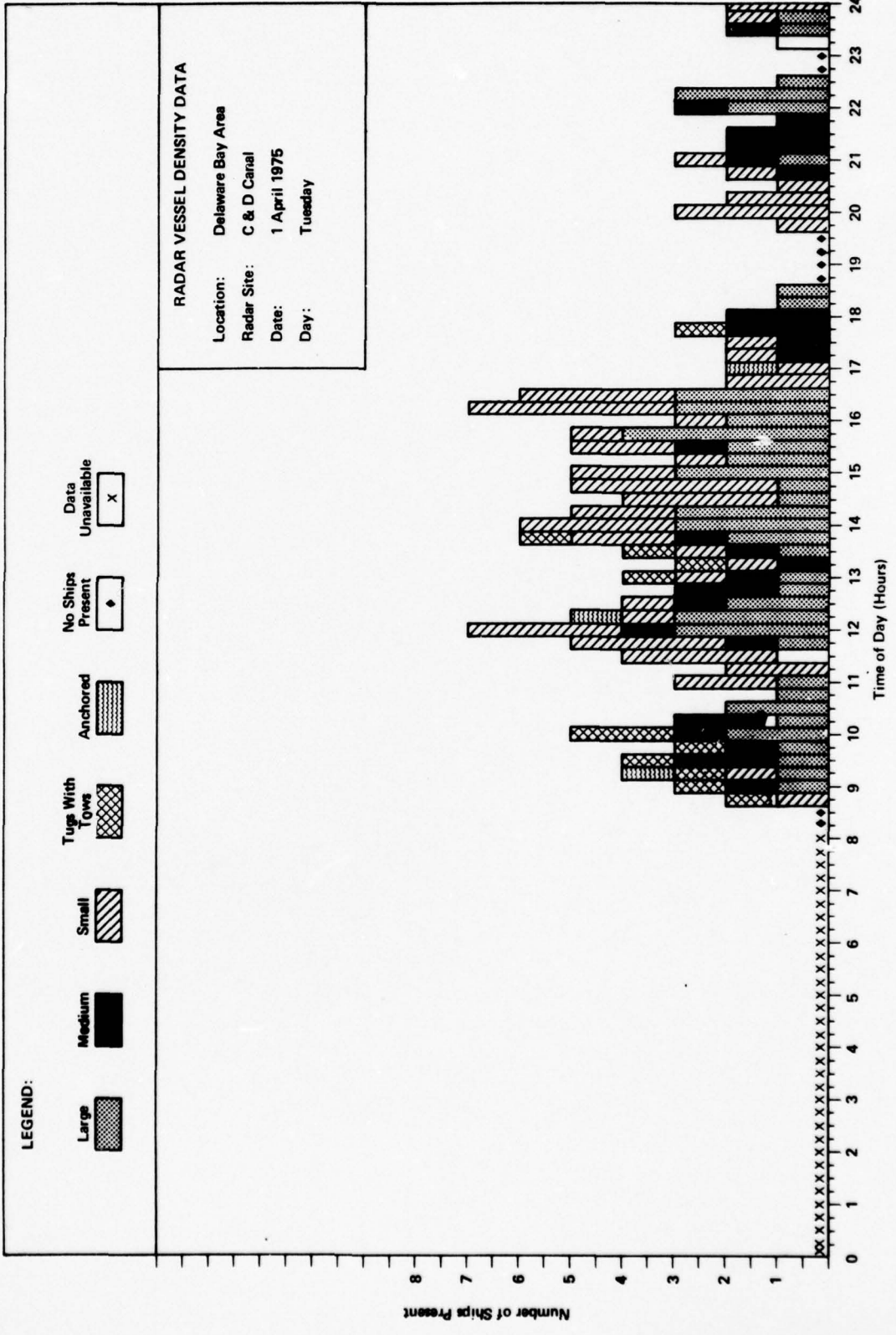
7. Channel Efficiency

Channel efficiency data are as follows:

	<u>Peak (%)</u>	<u>Average (%)</u>
Chesapeake and Delaware Canal	100	63
Philadelphia Naval Base	100	79

II. DATA

2.1 DATA FROM CHESAPEAKE AND DELAWARE CANAL

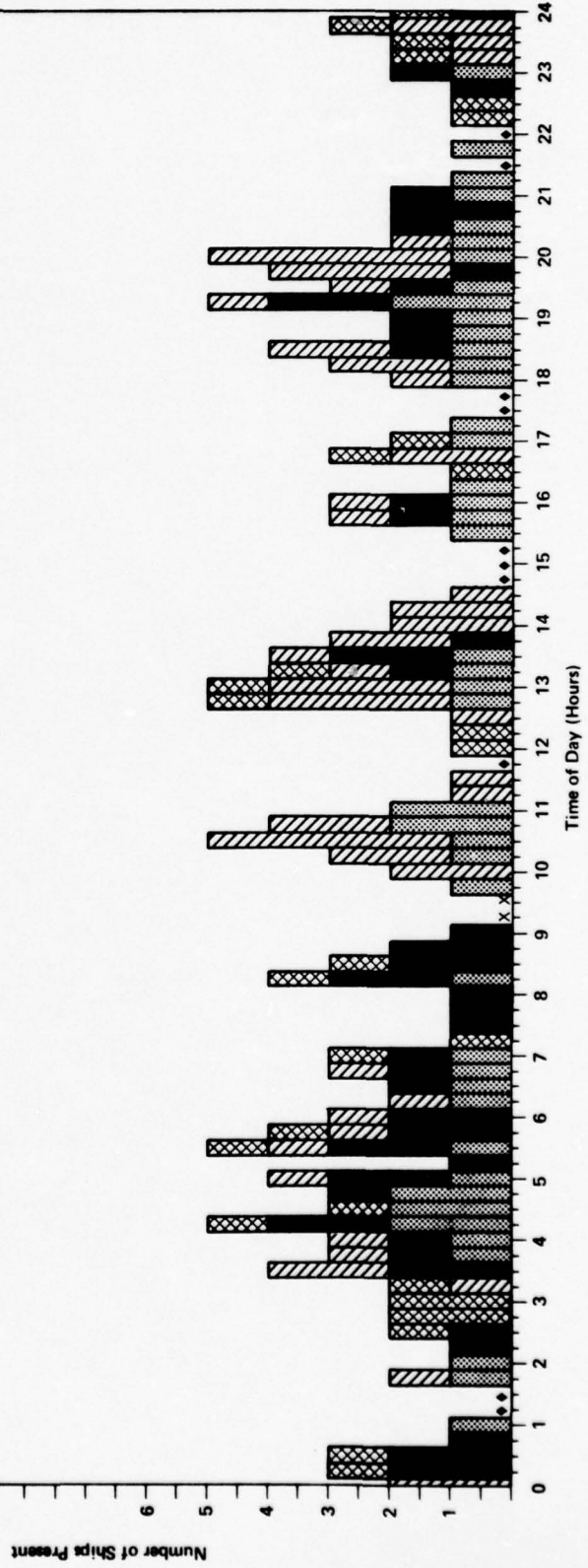


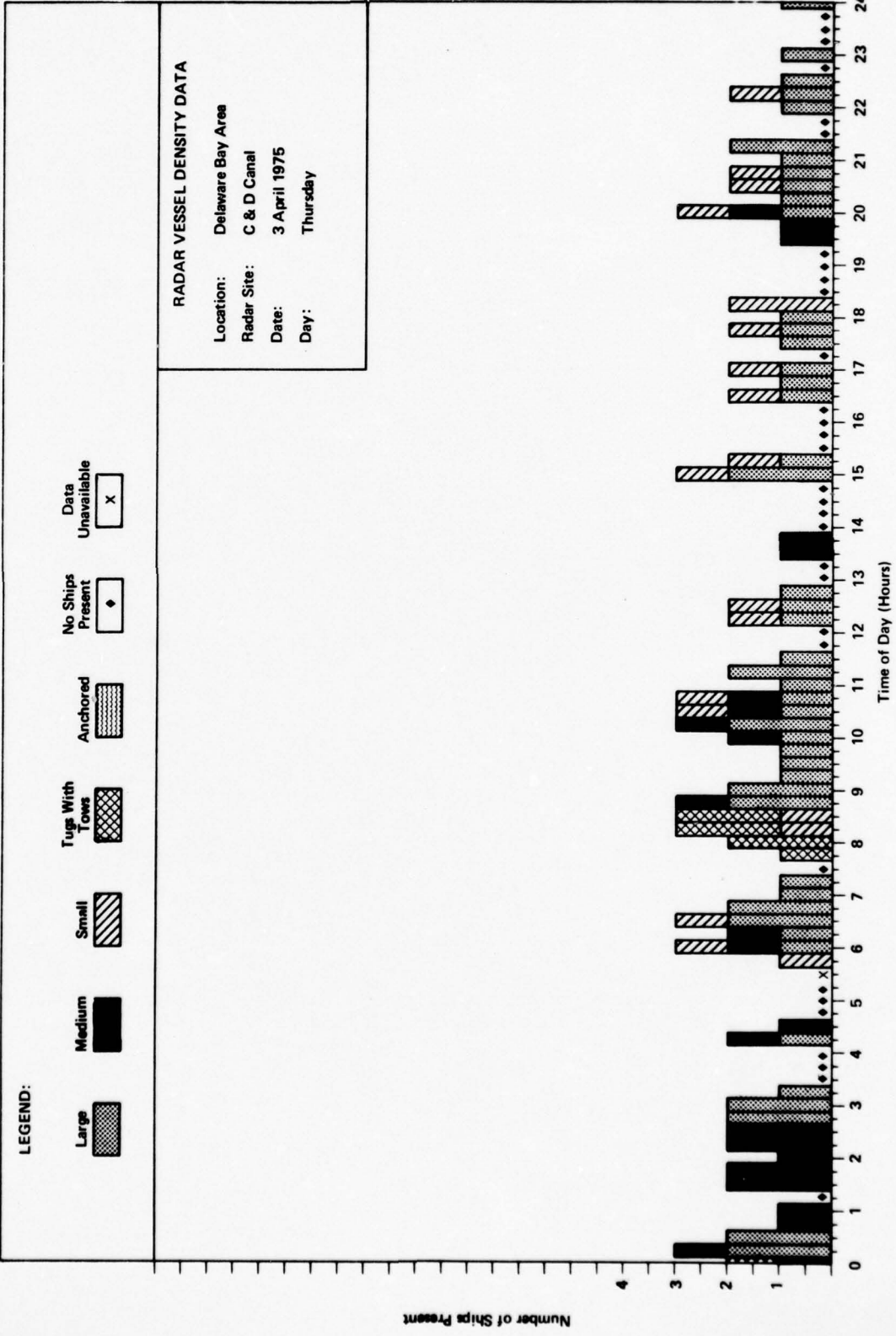
LEGEND:

- Large 
- Medium 
- Small 
- Tugs With Tows 
- Anchored 
- No Ships Present 
- Data Unavailable 

RADAR VESSEL DENSITY DATA

Location: Delaware Bay Area
 Radar Site: C & D Canal
 Date: 2 April 1975
 Day: Wednesday



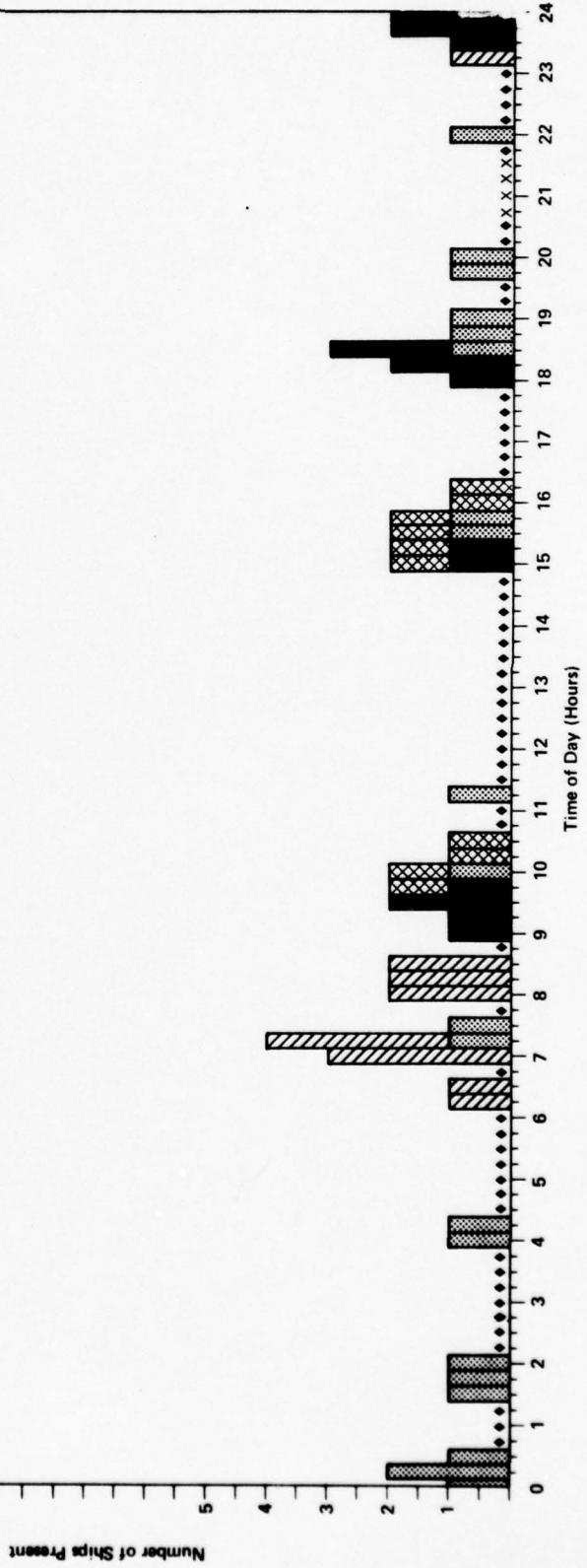


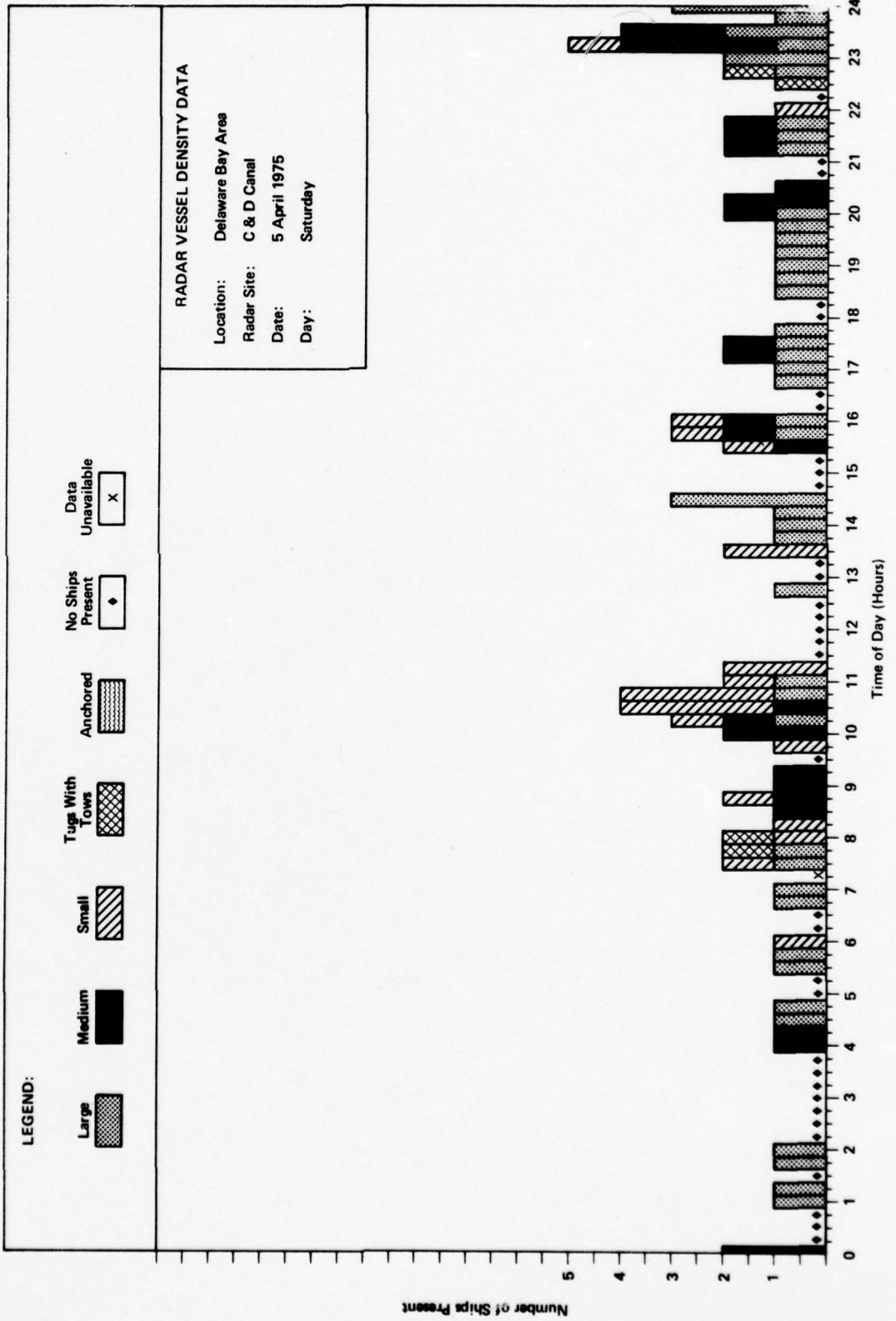
LEGEND:

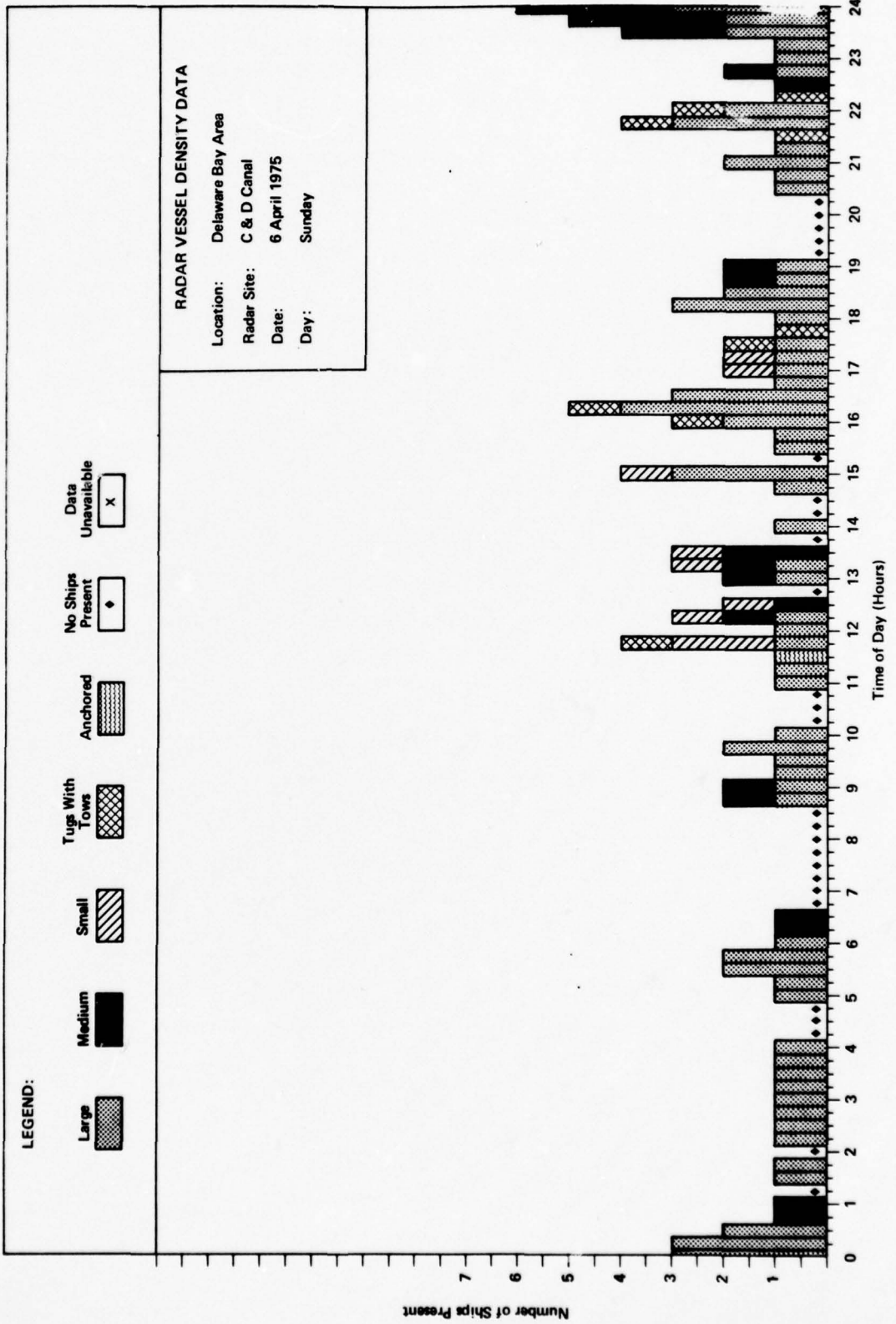
- Large 
- Medium 
- Small 
- Tugs With Tows 
- Anchored 
- No Ships Present 
- Data Unavailable 

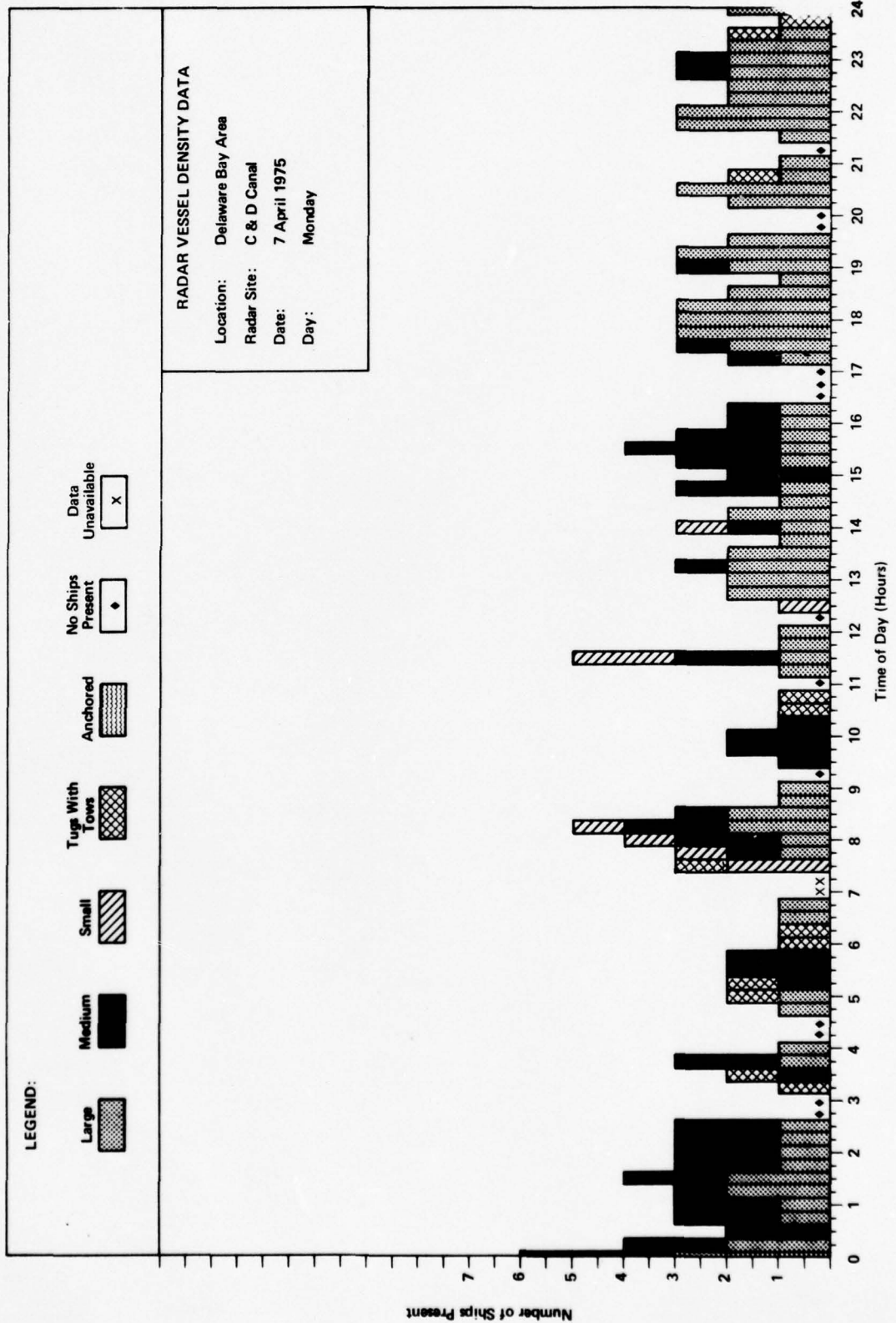
RADAR VESSEL DENSITY DATA

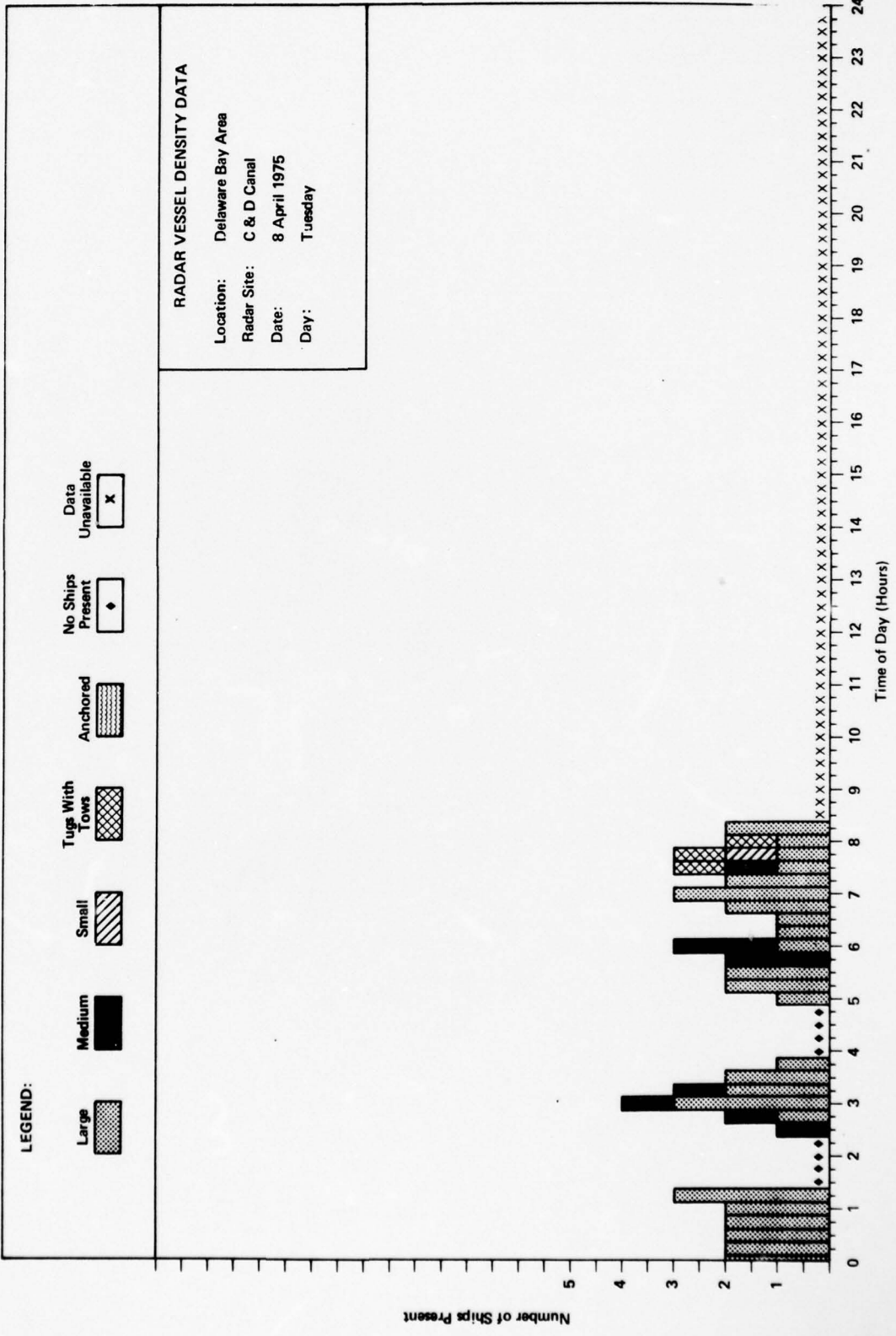
Location: Delaware Bay Area
 Radar Site: C & D Canal
 Date: 4 April 1975
 Day: Friday





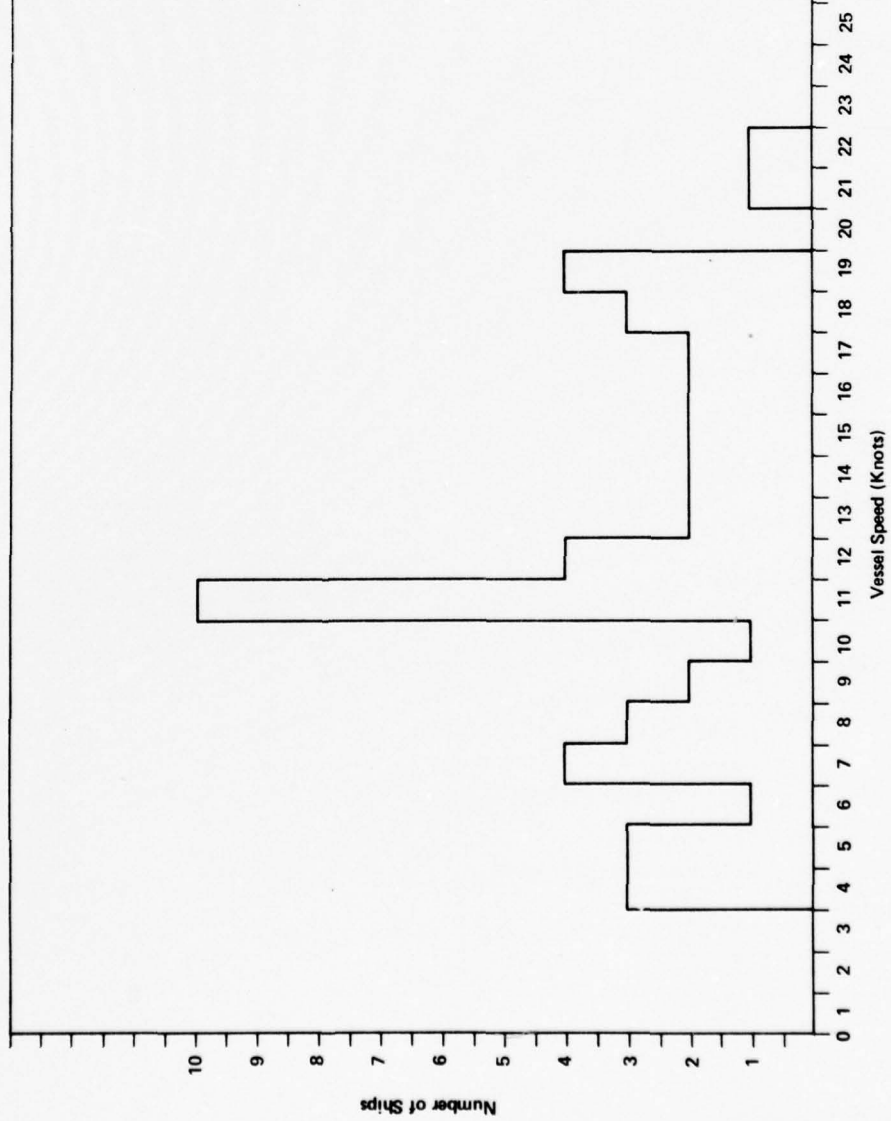







RADAR VESSEL SPEED DATA

Location: Delaware Bay Area
Sample Size: 50
Radar Site: C & D Canal
Date: 1, 2 April 1975
Day: Tuesday, Wednesday

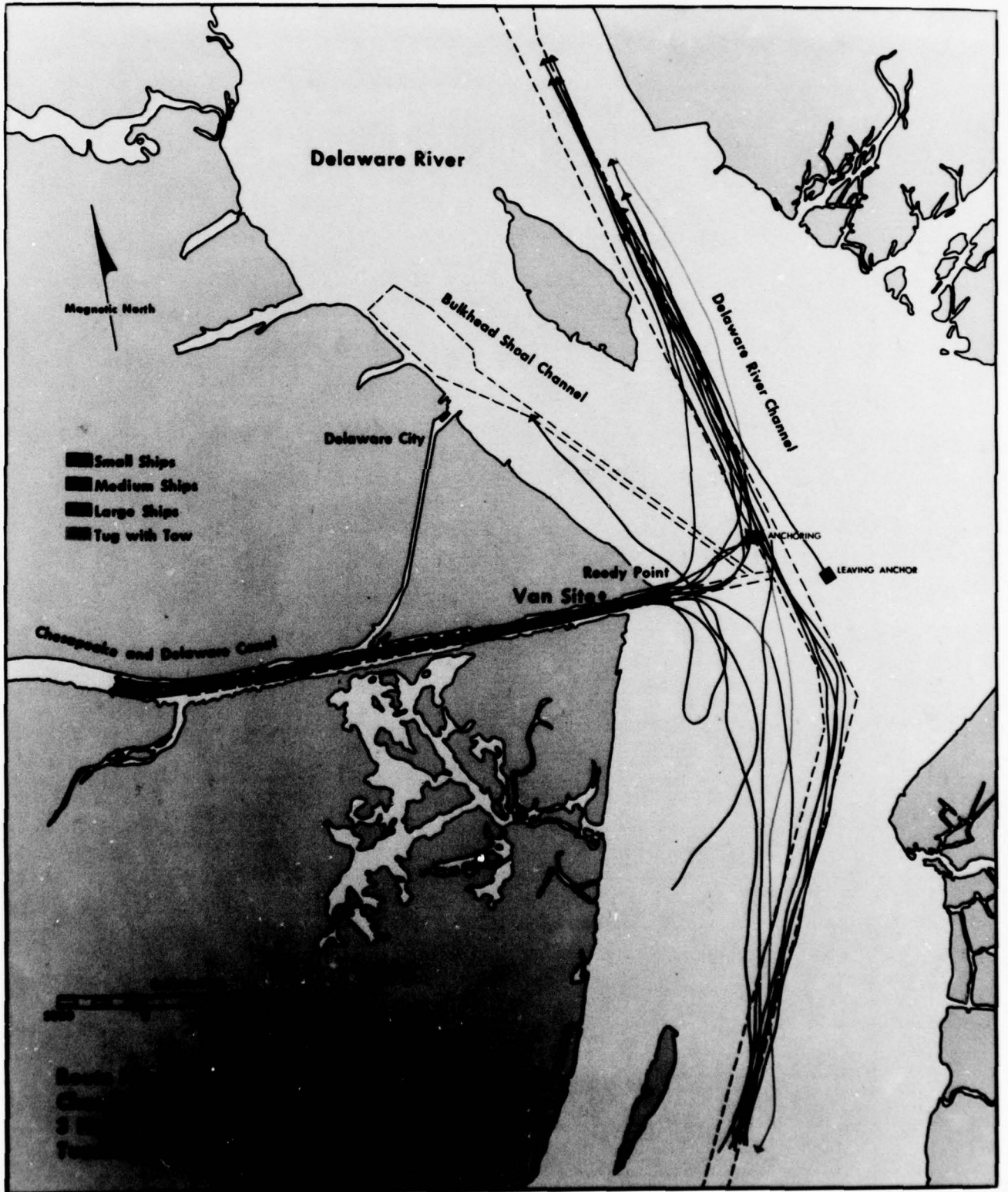


SPEED DATA
FOR
CHESAPEAKE AND DELAWARE CANAL

Vessel No.	Vessel Size	Average Speed in Knots	Direction	Day	Time Hour/Minute
1	large	12	N	Tuesday 1 April 1975 	08 41
2	large	4	N		08 43
3	small	16	N		08 56
4	small	14	E		09 04
5	tug	10	N		09 26
6	large	11	E		09 36
7	tug	13	S		09 50
8	large	12	N		09 59
9	large	17	N		10 29
10	medium	22	S		10 58
11	large	11	E		11 25
12	small	18	S		11 33
13	large	6	N		11 41
14	large	15	N		12 14
15	medium	4	W		12 22
16	medium	12	S		12 41
17	large	7	NW		12 50
18	medium	11	S		12 54
19	tug	8	S		12 55
20	large	4	S		13 24
21	large	19	N		13 24
22	large	18	N		13 42
23	small	11	E		14 28
24	small	21	NW		14 40
25	medium	19	W		14 47
26	small	5	S		14 55
27	medium	11	SE		Tuesday 1 April 1975

SPEED DATA
FOR
CHESAPEAKE AND DELAWARE CANAL (CONT'D)

Vessel No.	Vessel Size	Average Speed in Knots	Direction	Day	Time Hour/Minute
28	small	18	S	Tuesday	16 12
29	medium	7	N	1 April 1975	20 09
30	medium	8	S	Tuesday 1 April 1975	20 23
31	tug	5	S	Wednesday	02 17
32	large	12	N	2 April 1975	04 23
33	large	9	N		04 26
34	medium	11	E		04 32
35	large	15	S		04 38
36	medium	11	S		04 40
37	large	17	N		05 19
38	medium	5	S		05 21
39	large	19	S		05 35
40	medium	7	N		05 48
41	small	9	N		06 03
42	medium	7	S		06 16
43	large	16	N		06 18
44	large	19	N		06 41
45	tug	11	S		06 57
46	medium	8	S		07 26
47	large	13	S		08 15
48	medium	11	SE		08 17
49	medium	11	W	Wednesday	08 40
50	large	14	S	2 April 1975	10 09



CLOSE ENCOUNTER
FOR
CHESAPEAKE AND DELAWARE CANAL

No.	Day	Time Hour/Minute		Distance Yards	Size	Manner of Approach*
1	Tuesday 1 April 1975	09	00	120	1 large, 1 small	0
2		09	52	195	1 tug, 1 large	P
3		10	46	< 38	1 medium, 1 small	P
4		11	31	< 50	1 large, 1 small	P
5		11	32	< 75	1 large, 1 medium	P
6		11	35	< 38	1 medium, 1 small	0
7		11	43	< 30	1 medium, 1 small	P
8		11	47	< 38	1 medium, 1 small	P
9		11	56	< 30	2 small	P
10		12	33	200	1 large, 1 medium	0
11		12	45	180	2 medium	C
12		12	52	95	1 large, 1 small	0
13		13	38	75	1 large, 1 small	P
14		13	44	75	1 large, 1 small	P
15		13	54	195	1 large, 1 small	C
16		13	57	165	1 large, 1 medium	P
17		13	57	115	2 large	P
18		14	09	175	1 large, 1 medium	P
19		14	13	150	2 large	0
20		14	14	170	2 large	P
21		14	15	100	2 large	P
22		14	41	< 25	2 small	P
23		14	42	< 25	2 small	P
24		14	44	< 45	2 small	P
25		14	58	140	2 large	P
26	Tuesday	15	18	100	1 large, 1 small	0
27	1 April 1975	15	20	140	2 large	P

*P = Passing
0 = Overtaking
C = Crossing

< = less than

CLOSE ENCOUNTER
FOR
CHESAPEAKE AND DELAWARE CANAL (CONT'D)

No.	Day	Time Hour/Minute		Distance Yards	Size	Manner of Approach*
28	Tuesday	14	45	145	2 large	P
29	1 April 1975	15	48	175	2 large	P
30	↑ ↓	15	56	110	2 large	P
31		16	15	100	2 small	P
32		16	24	<30	2 small	P
33		16	25	90	2 small	P
34		Tuesday	17	44	125	1 tug, 1 medium
35	1 April 1975	23	33	95	2 large	P
36	Wednesday	02	29	195	1 large, 1 medium	P
37	2 April 1975	02	54	<75	1 large, 1 medium	P
38	↑ ↓	05	24	80	1 medium, 1 small	O
39		05	35	100	1 large, 1 medium	P
40		05	48	100	1 large, 1 small	P
41	Wednesday	06	31	145	1 large, 1 medium	P
42	2 April 1975	06	49	110	1 large, 1 small	P

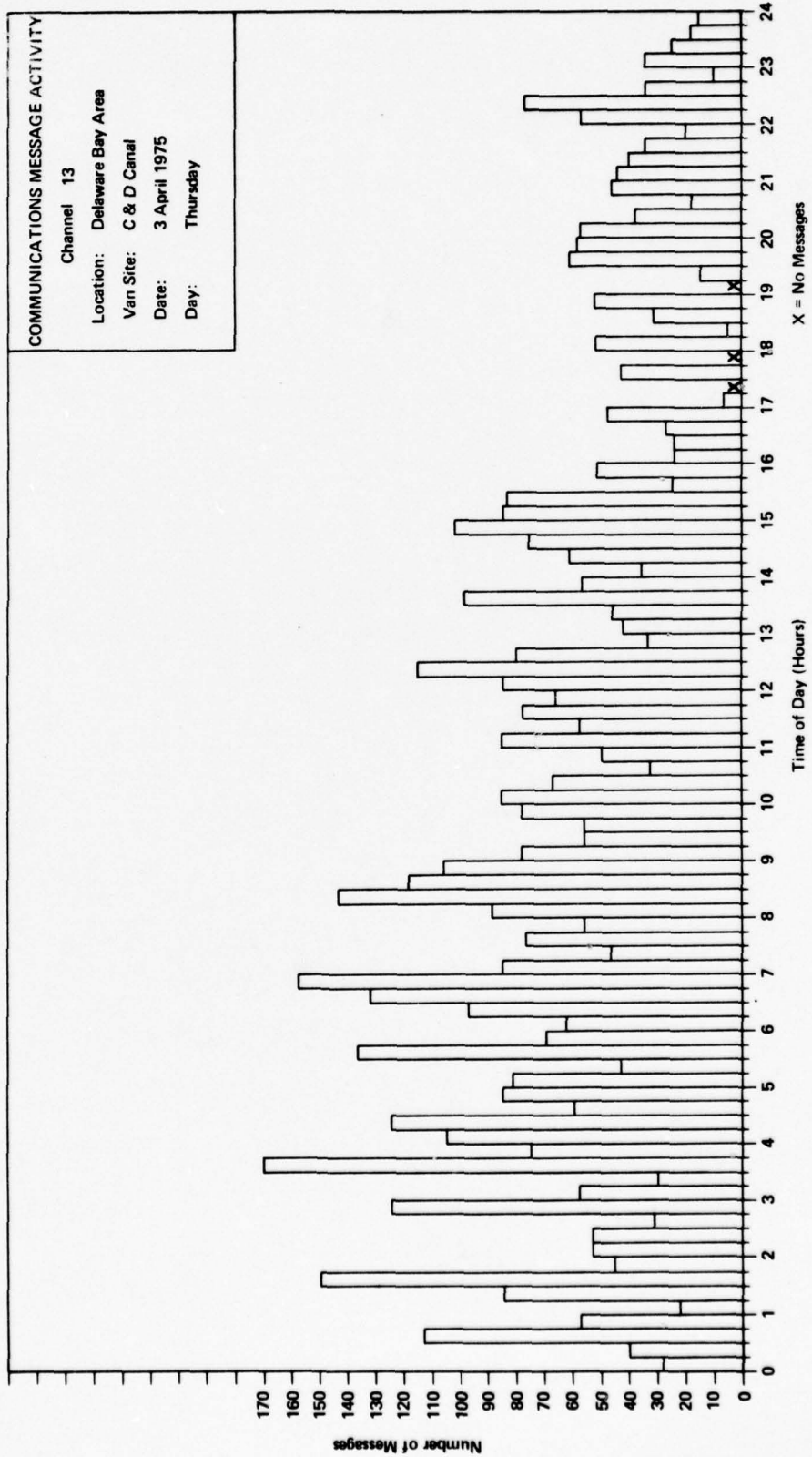
42 close encounters out of 98 encounters in 24 hours.

*P = Passing
O = Overtaking
C = Crossing

< = less than

COMMUNICATIONS MESSAGE ACTIVITY

Channel 13
Location: Delaware Bay Area
Van Site: C & D Canal
Date: 3 April 1975
Day: Thursday



COMMUNICATIONS CHANNEL
UTILIZATION

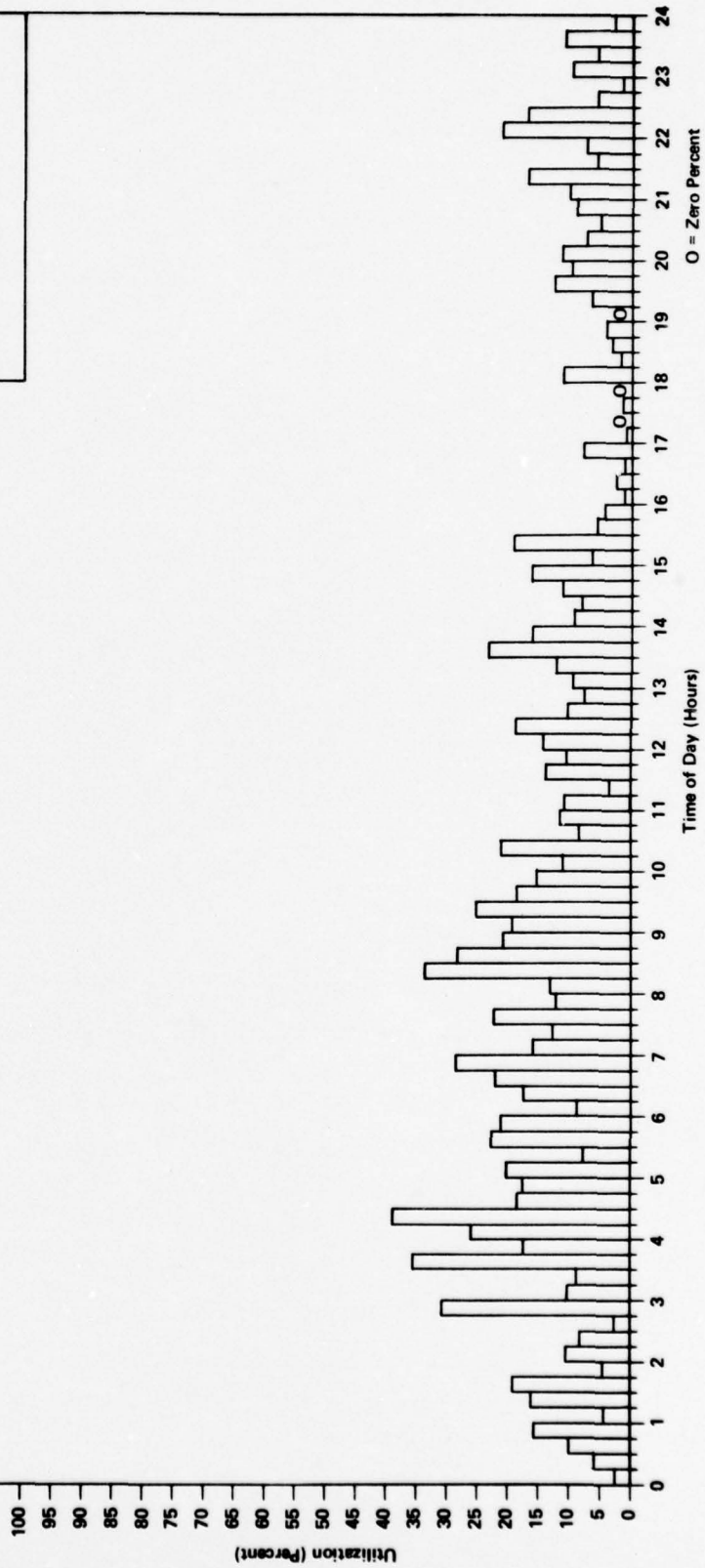
Channel 13

Location: Delaware Bay Area

Van Site: C & D Canal

Date: 3 April 1975

Day: Thursday



**COMMUNICATIONS CHANNEL
EFFICIENCY**

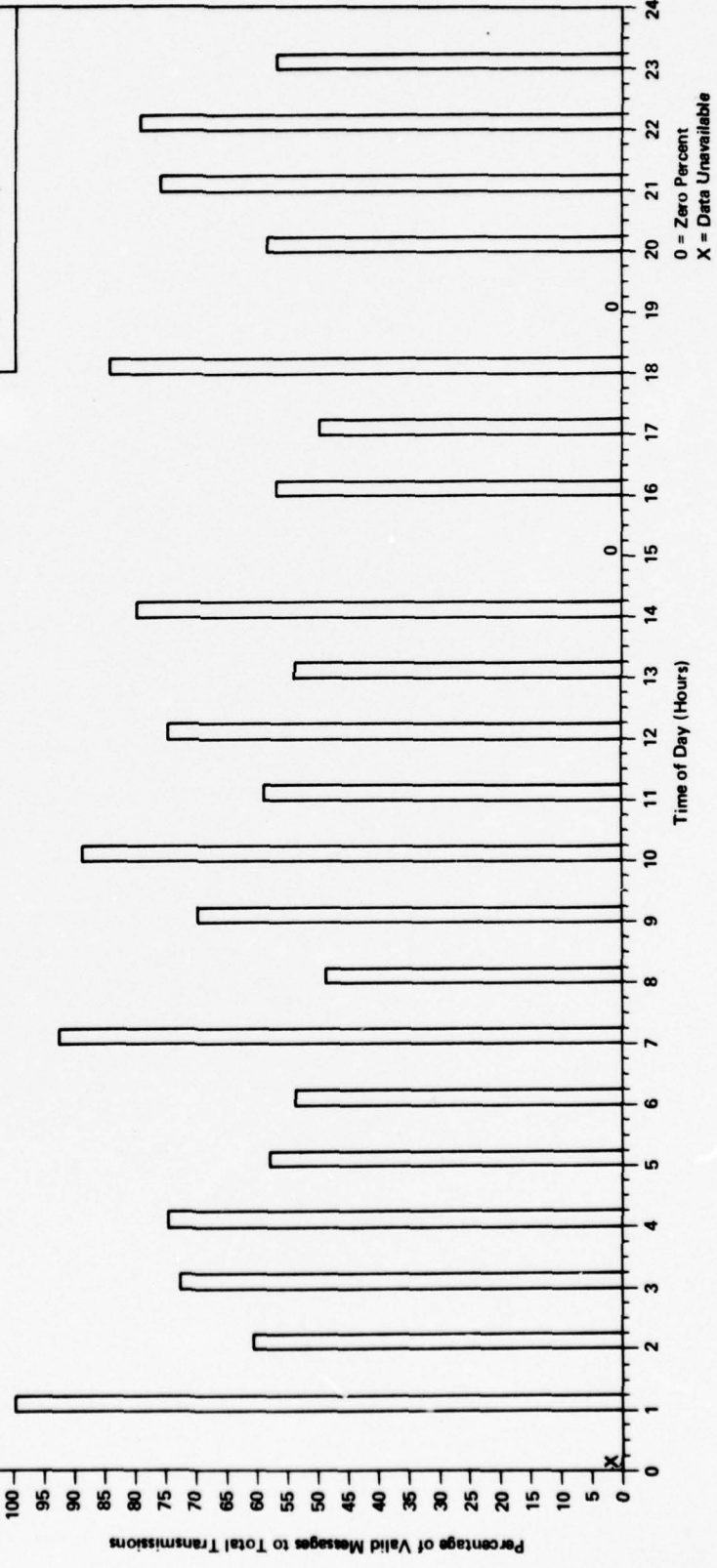
Channel 13

Location: Delaware Bay Area

Van Site: C & D Canal









Date: 3 April 1975

Day: Thursday



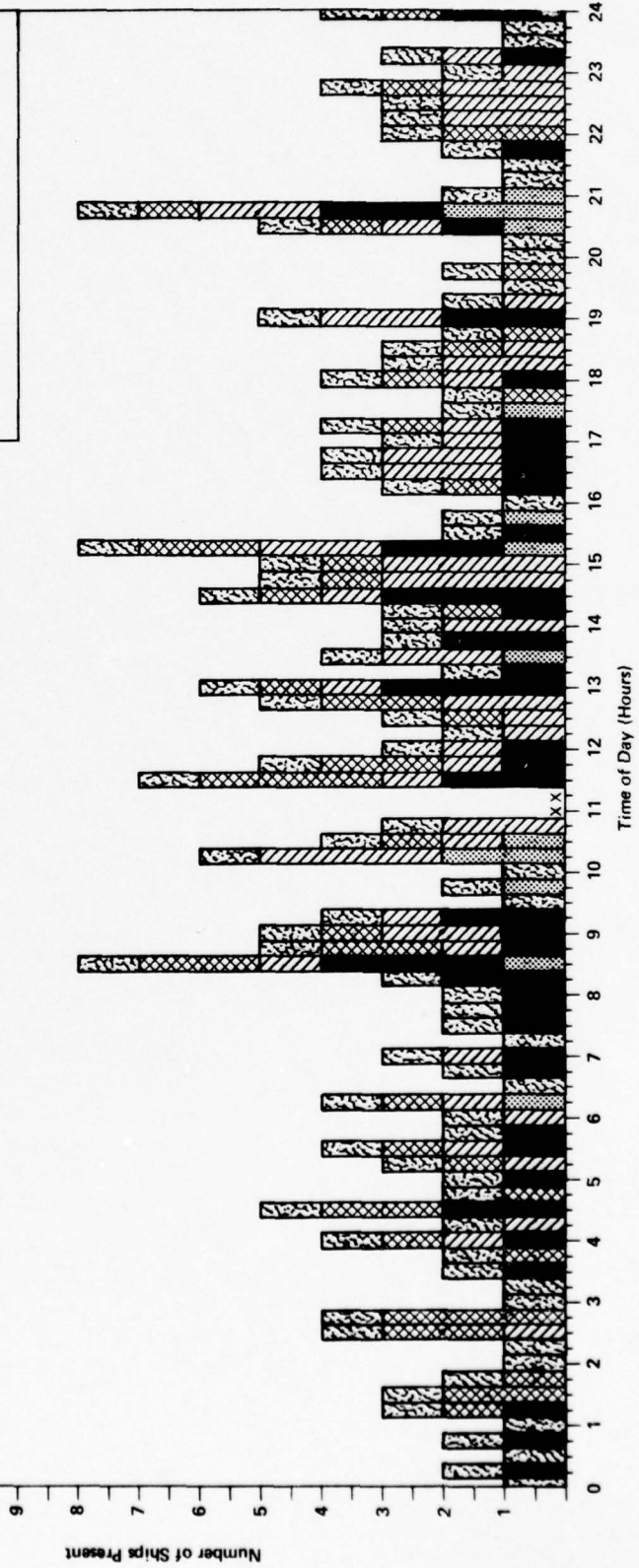
2.2 DATA FROM PHILADELPHIA NAVAL BASE

LEGEND:









- Large 
- Medium 
- Small 
- Tugs with Tow 
- Dredges 
- Anchored 
- No Ships Present 
- Data Unavailable 

RADAR VESSEL DENSITY DATA

Location: Delaware Bay Area
 Radar Site: Philadelphia Naval Base
 Date: 9 April 1975
 Day: Wednesday

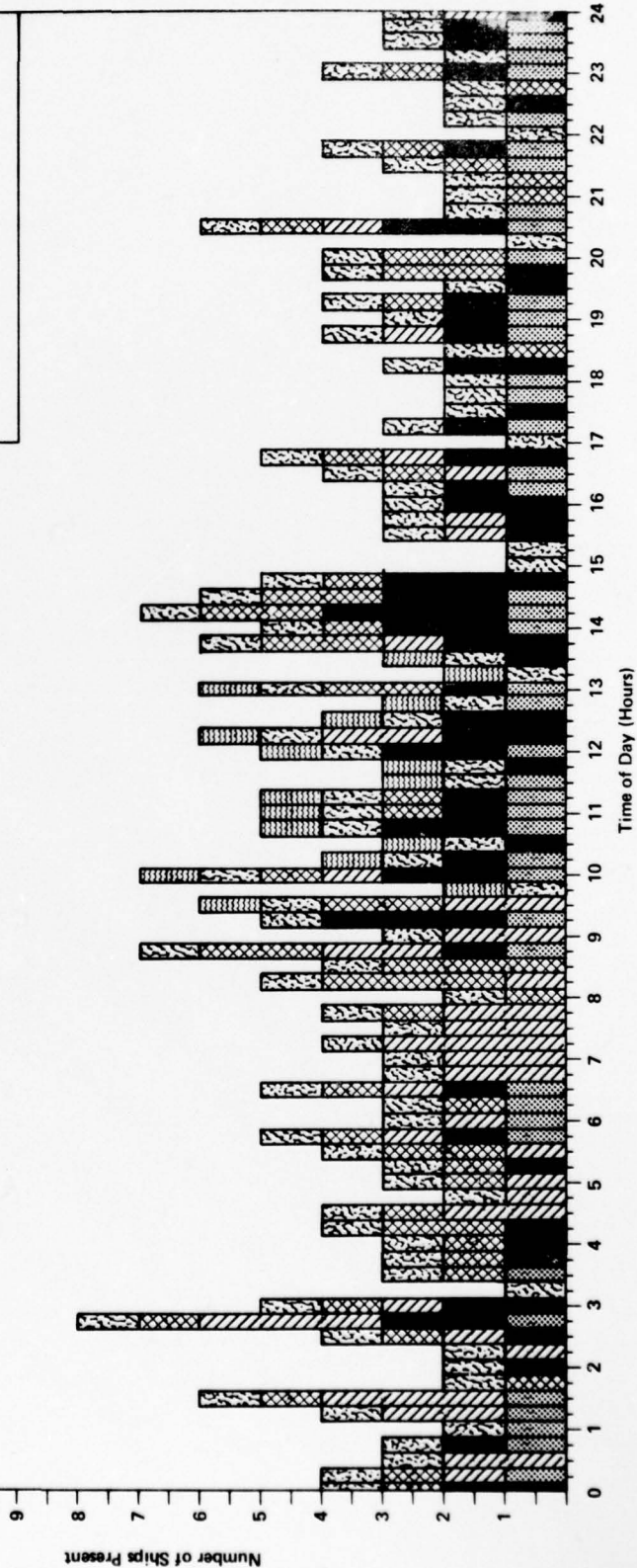


LEGEND:

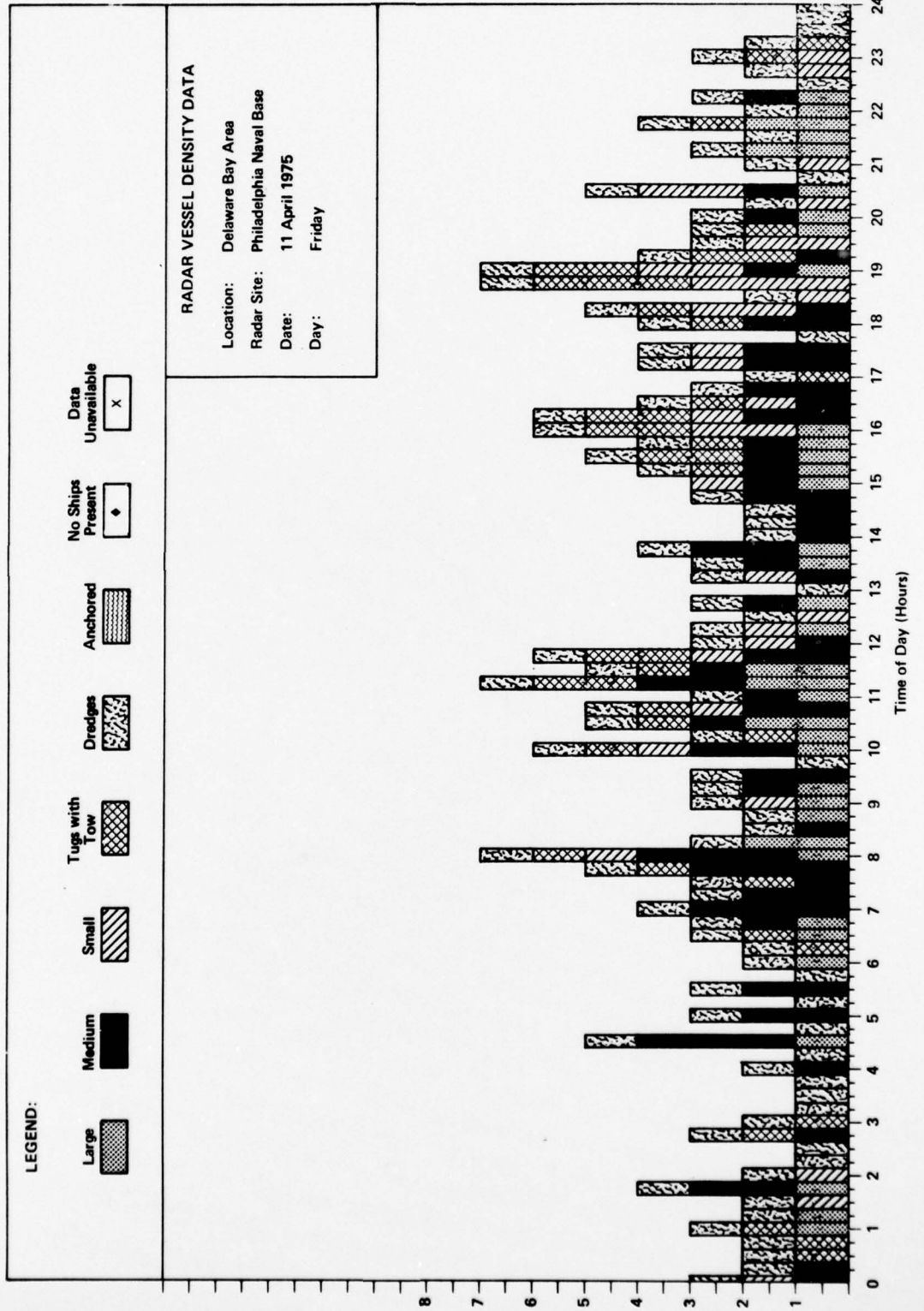
- Large 
- Medium 
- Small 
- Tugs with Tow 
- Dredges 
- Anchored 
- No Ships Present 
- Data Unavailable 

RADAR VESSEL DENSITY DATA









Location: Delaware Bay Area
 Radar Site: Philadelphia Naval Base
 Date: 10 April 1975
 Day: Thursday



Number of Ships Present

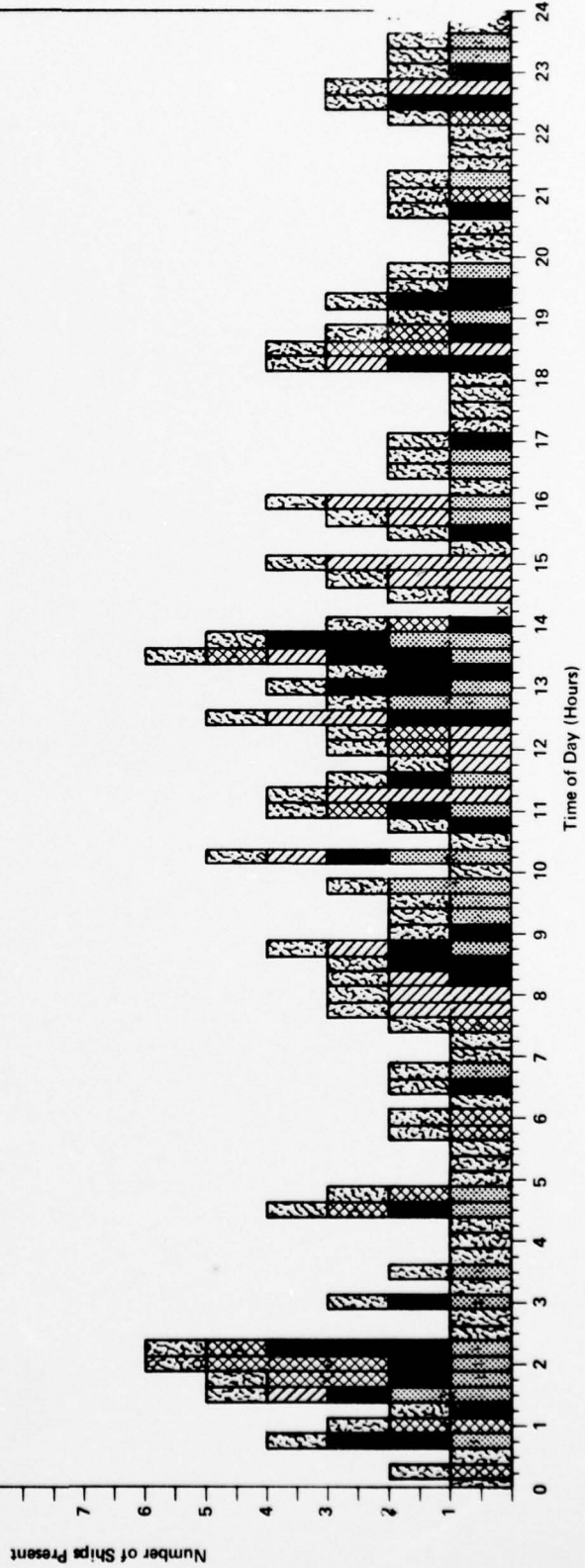


LEGEND:





- Large 
- Medium 
- Small 
- Tugs with Tow 
- Dredges 
- Anchored 
- No Ships Present 
- Data Unavailable 

RADAR VESSEL DENSITY DATA

Location: Delaware Bay Area
 Radar Site: Philadelphia Naval Base
 Date: 12 April 1975
 Day: Saturday

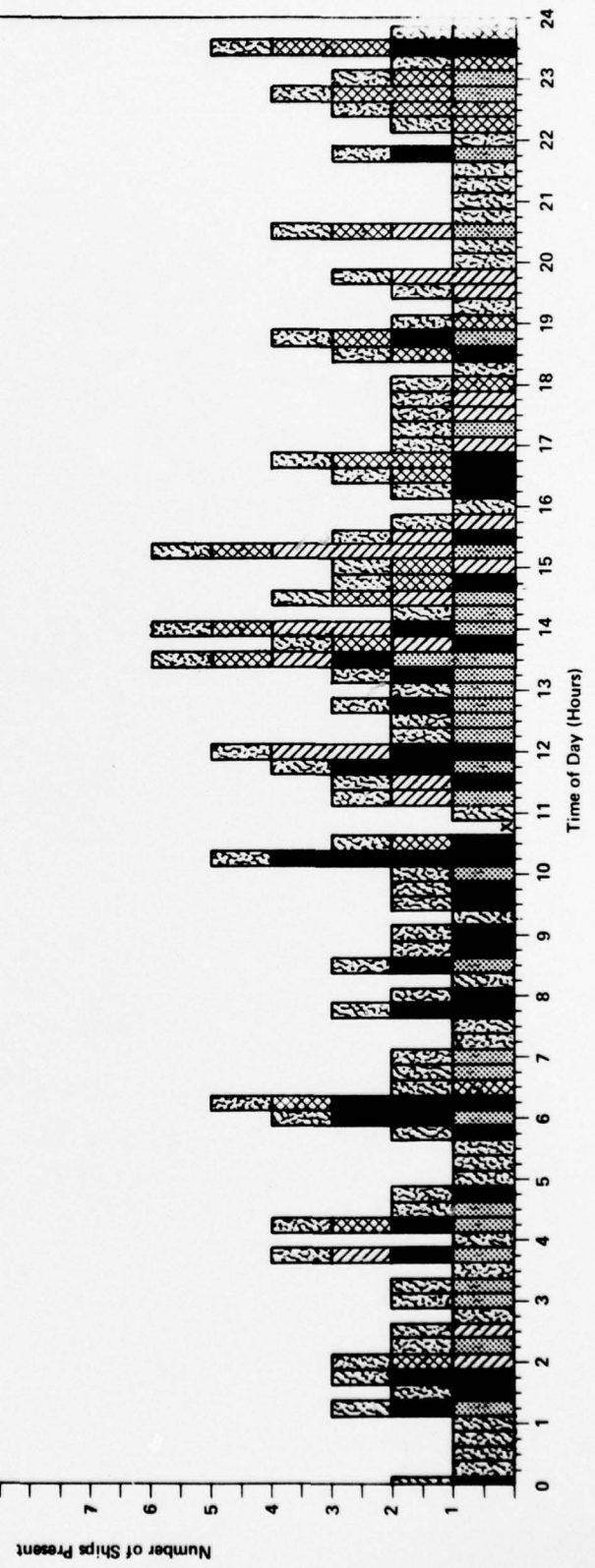


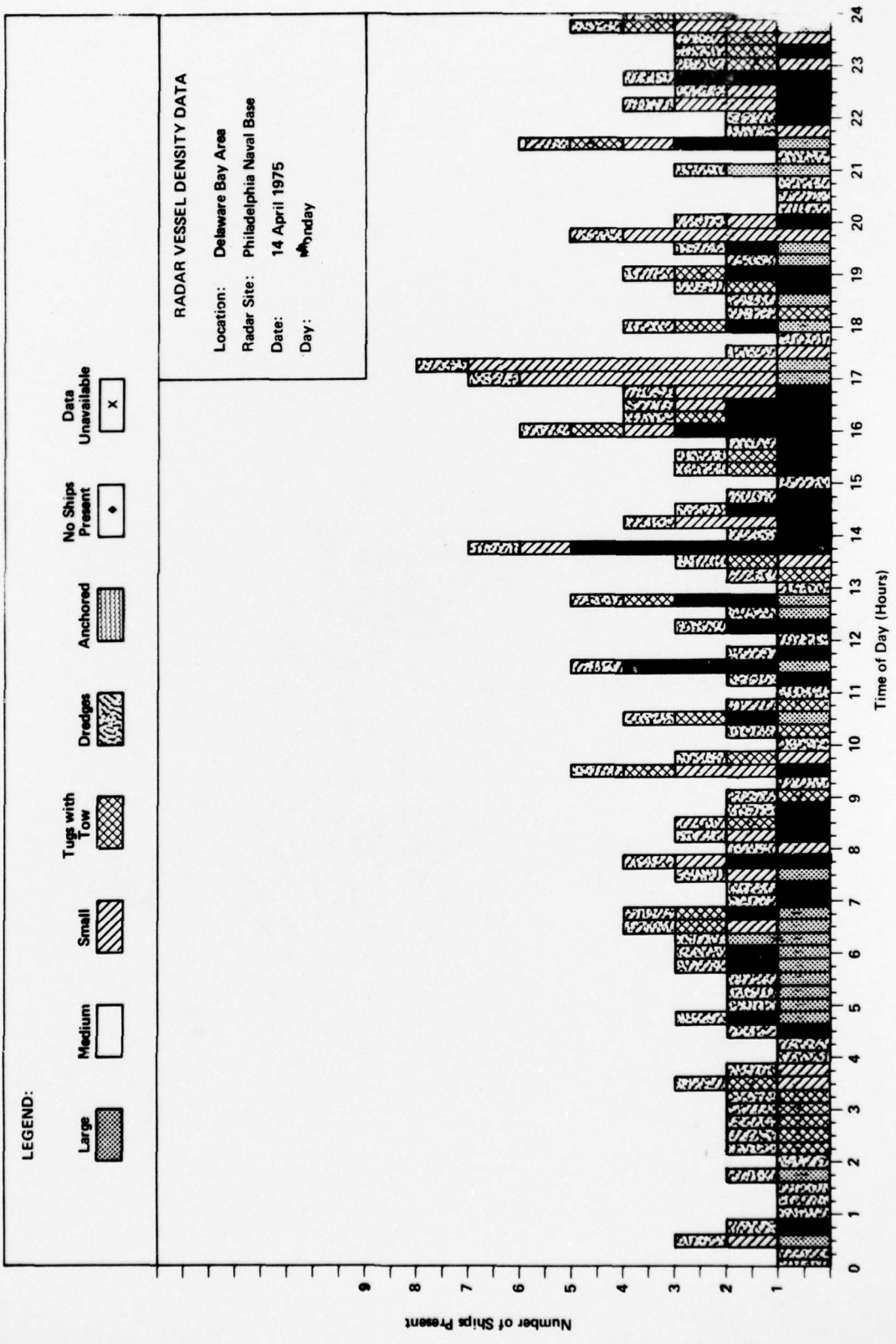
LEGEND:

- Large 
- Medium 
- Small 
- Tugs with Tow 
- Dredges 
- Anchored 
- No Ships Present 
- Data Unavailable 









RADAR VESSEL DENSITY DATA

Location: Delaware Bay Area
 Radar Site: Philadelphia Naval Base
 Date: 13 April 1975
 Day: Sunday



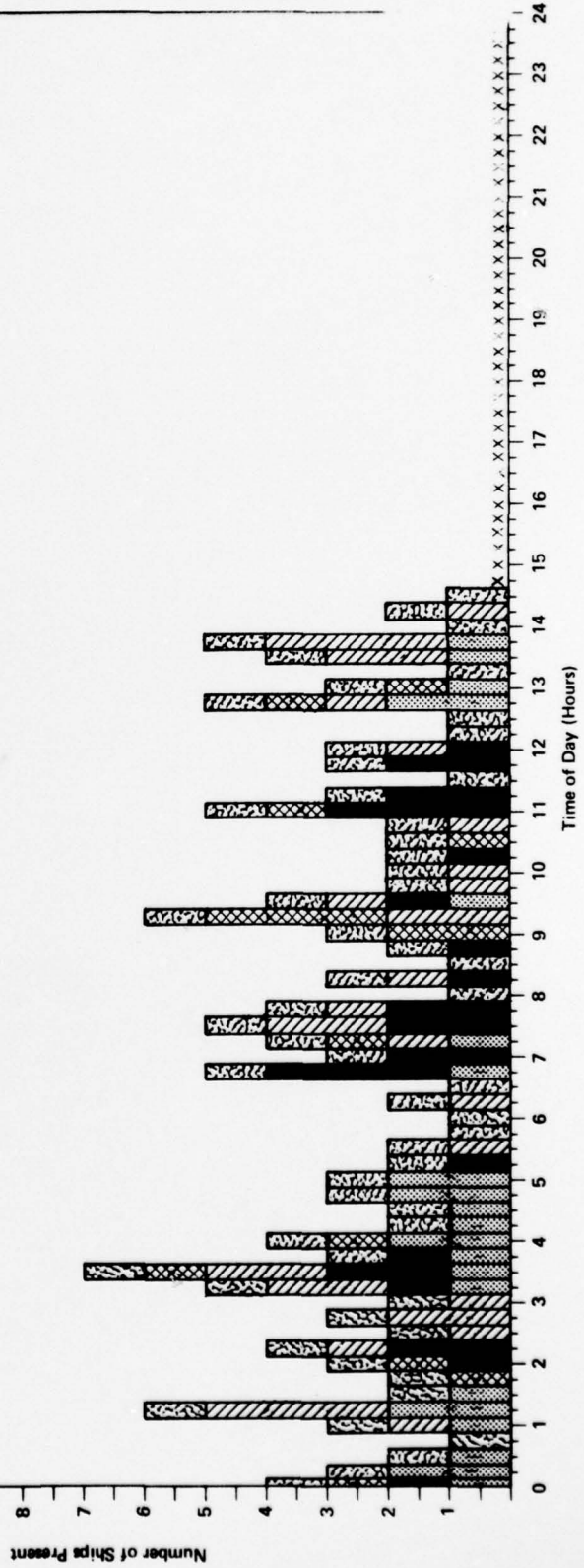


LEGEND:

- Large 
- Medium 
- Small 
- Tugs with Tow 
- Dredges 
- Anchored 
- No Ships Present 
- Data Unavailable 

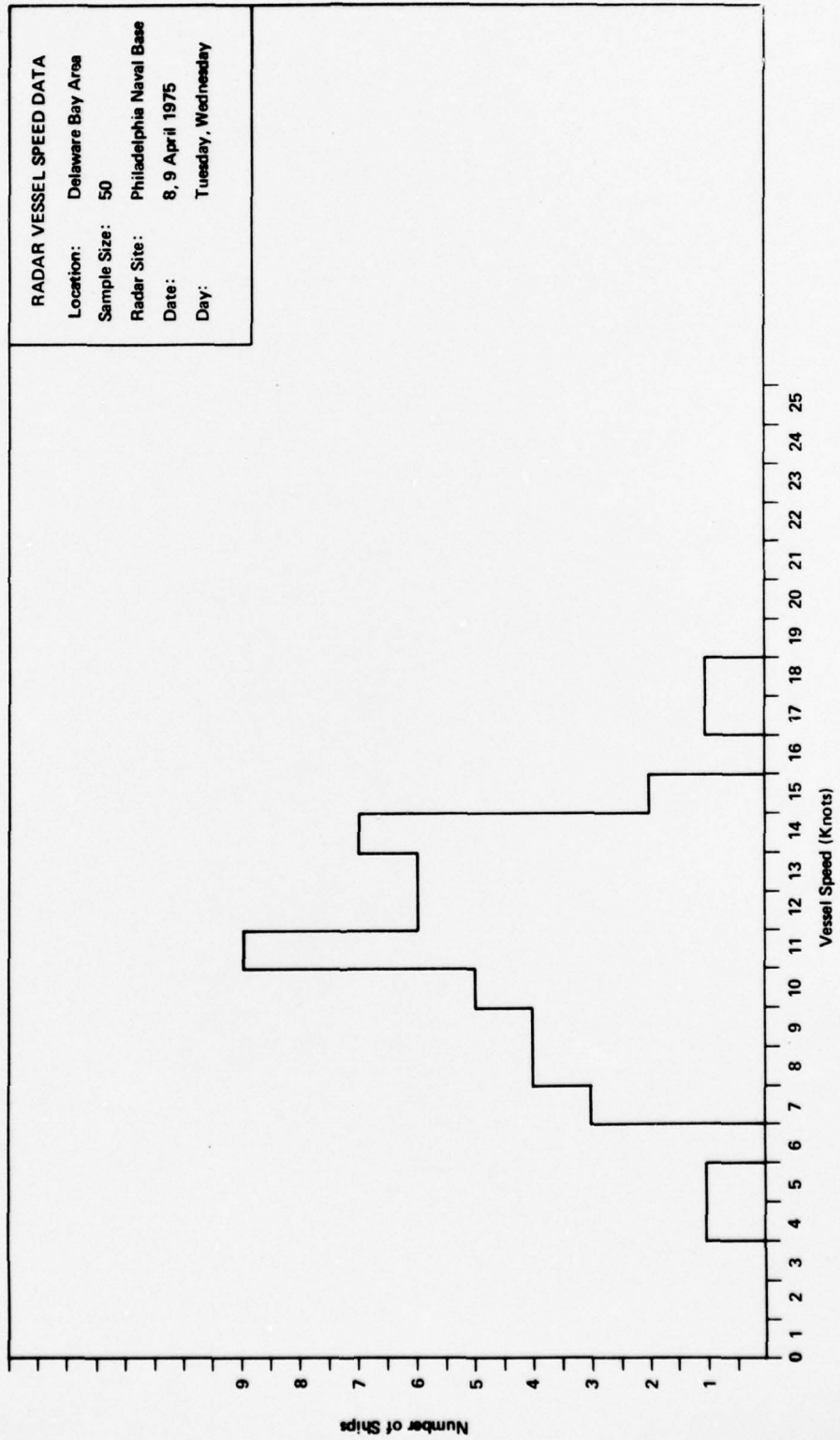
RADAR VESSEL DENSITY DATA

Location: Delaware Bay Area
 Radar Site: Philadelphia Naval Base
 Date: 15 April 1975
 Day: Tuesday



RADAR VESSEL SPEED DATA

Location: Delaware Bay Area
Sample Size: 50
Radar Site: Philadelphia Naval Base
Date: 8, 9 April 1975
Day: Tuesday, Wednesday

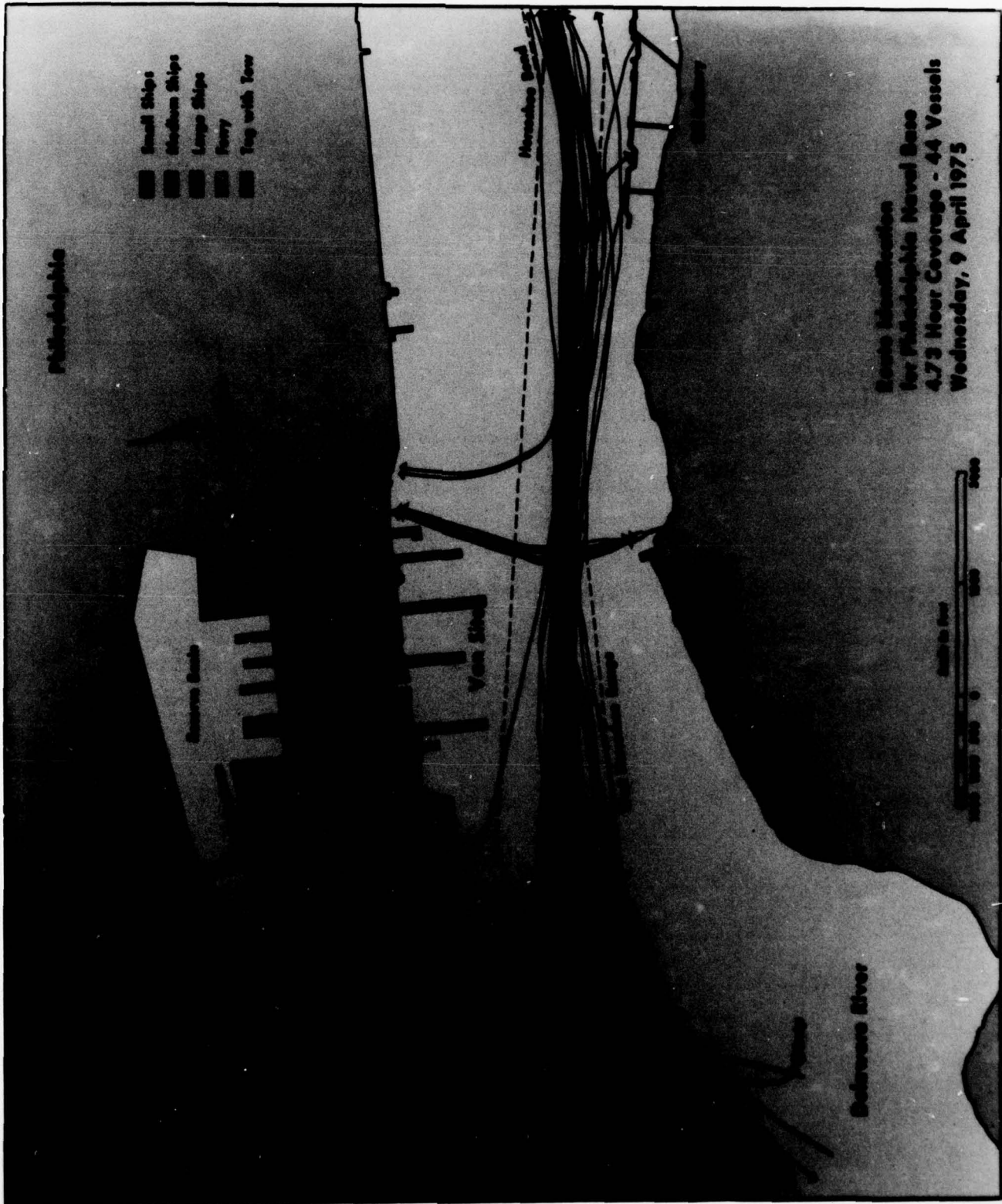


SPEED DATA
FOR
PHILADELPHIA NAVAL BASE

Vessel No.	Vessel Size	Average Speed in Knots	Direction	Day	Time Hour/Minute	
1	medium	15	W	Tuesday 8 April 1975	15 33	
2	medium	14	W		16 13	
3	medium	8	E	↑ ↓	16 14	
4	small	10	E		17 06	
5	small	8	E		17 08	
6	tug with tow	5	E		17 10	
7	large	4	E		17 36	
8	large	12	W		17 47	
9	large	10	W		17 49	
10	medium	13	W		17 55	
11	tug with tow	11	E		18 25	
12	medium	11	E		18 46	
13	small	15	W		18 56	
14	medium	7	W		19 14	
15	large	13	W		20 32	
16	medium	8	E		20 37	
17	medium	12	W		20 43	
18	small	17	E		20 59	
19	large	14	W		21 07	
20	tug with tow	8	E		21 07	
21	tug with tow	11	W		21 20	
22	large	14	E		21 26	
23	large	12	E		21 46	
24	medium	12	E		Tuesday 8 April 1975	22 11
25	medium	14	E		Wednesday 9 April 1975	00 09
26	medium	13	E		01 03	
27	large	13	E		01 35	

SPEED DATA
FOR
PHILADELPHIA NAVAL BASE (CONT'D)

Vessel No.	Vessel Size	Average Speed in Knots	Direction	Day	Time Hour/Minute
28	tug with tow	7	E	Wednesday 9 April 1975	02 27
29	tug with tow	9	W		02 31
30	tug with tow	10	W	↑ ↓	02 38
31	medium	10	E		03 46
32	tug with tow	10	W		03 50
33	medium	14	W		04 26
34	medium	14	W		04 28
35	large	11	E		04 30
36	medium	9	W		04 50
37	small	12	W		05 13
38	large	7	E		05 15
39	medium	9	W		05 24
40	small	11	W		06 00
41	large	9	W		06 10
42	small	13	W		06 51
43	medium	13	W		08 09
44	medium	14	W		08 09
45	medium	12	W		08 28
46	medium	11	W		09 08
47	small	11	E		09 13
48	large	18	E		09 45
49	large	11	E		10 10
50	large	11	E	Wednesday 9 April 1975	10 16



CLOSE ENCOUNTER
FOR
PHILADELPHIA NAVAL BASE

No.	Day	Time Hour/Minute		Distance Yards	Size	Manner of Approach*
1	Wednesday 9 April 1975 ↑ ↓	08	11	85	2 medium	0
2		08	29	60	1 medium, 1 small	0
3		08	30	80	1 medium, 1 small	0
4		08	31	112	1 medium, 1 small	0
5		08	32	80	1 medium, 1 small	0
6		08	36	80	1 large, 1 small	0
7		08	42	55	1 medium, 1 small	P
8		08	46	135	1 tug, 1 large	0
9		08	50	125	1 tug, 1 small	0
10		08	50	100	1 large, 1 small	P
11		08	50	112	1 tug, 1 large	P
12		08	57	80	1 medium, 1 small	0
13		08	58	55	1 medium, 1 small	0
14		09	17	115	1 medium, 1 small	P
15		10	07	120	1 large, 1 small	P
16		10	18	135	1 large, 1 small	P
17		10	21	70	1 large, 1 medium	P
18		10	27	96	1 large, 1 small	P
19		10	30	110	1 tug, 1 small	P
20		11	25	135	1 large, 1 small	P
21		11	27	100	2 medium	P
22		11	29	75	1 large, 1 small	P
23		11	30	100	2 large	0
24		12	42	< 25	1 tug, 1 large,	0
25		12	50	80	2 small	P
26		12	55	80	1 medium, 1 small	C
27		Wednesday	13	01	50	2 small
28	9 April 1975	13	09	120	1 large, 1 small	P

*P = Passing
0 = Overtaking
C = Crossing

< = less than

CLOSE ENCOUNTER
FOR
PHILADELPHIA NAVAL BASE (CONT'D)

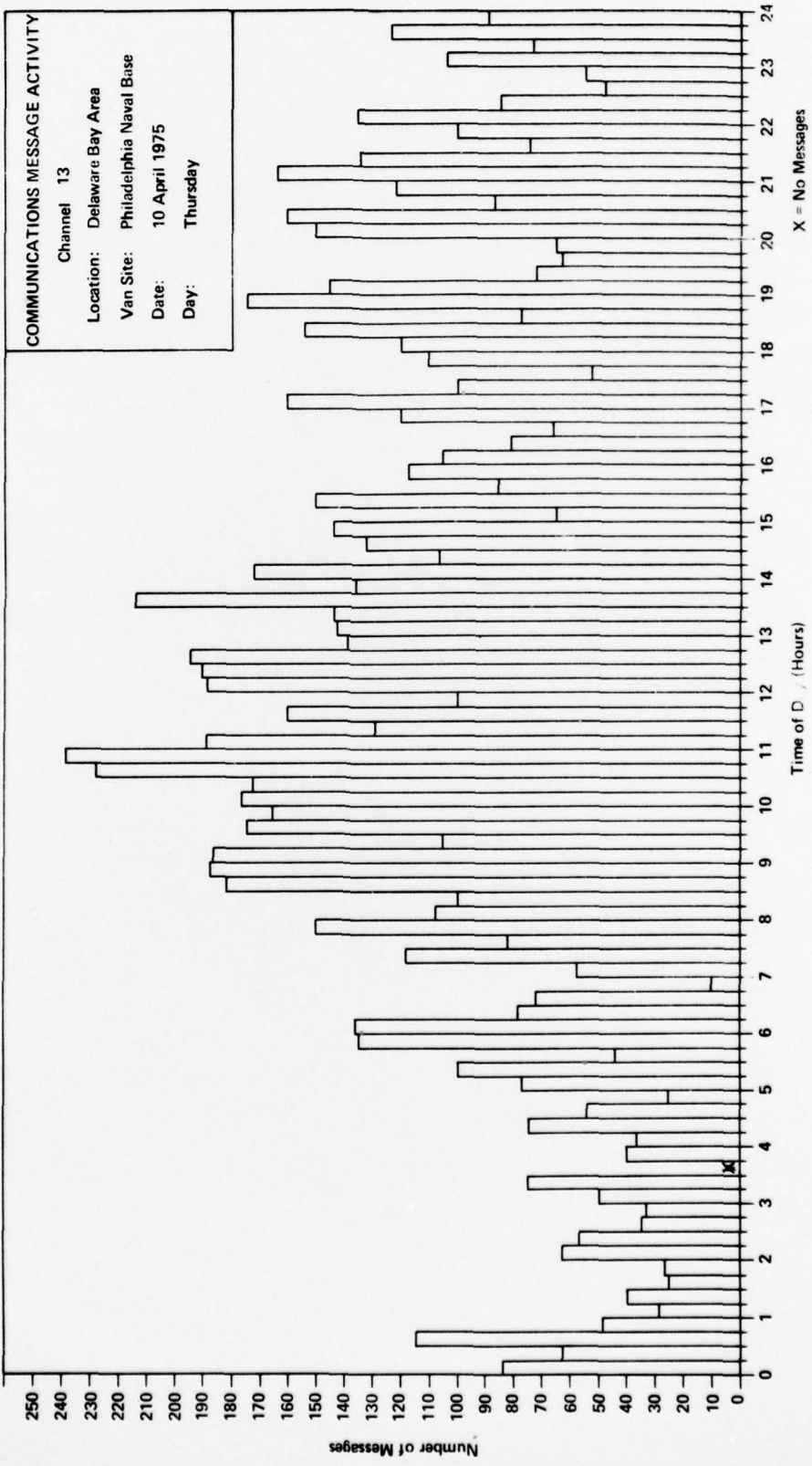
No.	Day	Time Hour/Minute		Distance Yards	Size	Manner of Approach*
29	Wednesday 9 April 1975	13	32	122	1 tug, 1 small	P
30		13	35	80	1 large, 1 small	P
31	↑ ↓	13	47	122	2 medium	P
32		14	12	125	2 large	P
33		14	24	100	2 large	P
34		14	43	75	1 medium, 1 small	P
35		14	57	100	2 medium	P
36		15	04	105	2 medium	P
37		15	05	85	1 large, 1 small	P
38		15	09	120	2 medium	P
39		15	11	120	1 medium, 1 small	P
40		15	12	82	1 large, 1 small	P
41		15	15	75	1 large, 1 medium	P
42		15	16	60	1 large, 1 medium	P
43		15	17	55	2 medium	P
44		16	36	72	2 medium	P
45		17	07	84	2 medium	O
46		17	08	52	1 medium, 1 small	P
47		17	09	48	1 medium, 1 small	P
48		17	13	135	1 large, 1 small	P
49		18	01	140	2 medium	P
50		Wednesday	18	13	122	2 small
51	9 April 1975	18	21	125	2 medium	P

51 close encounters out of 82 encounters in 7 hours coverage.

*P = Passing
O = Overtaking
C = Crossing

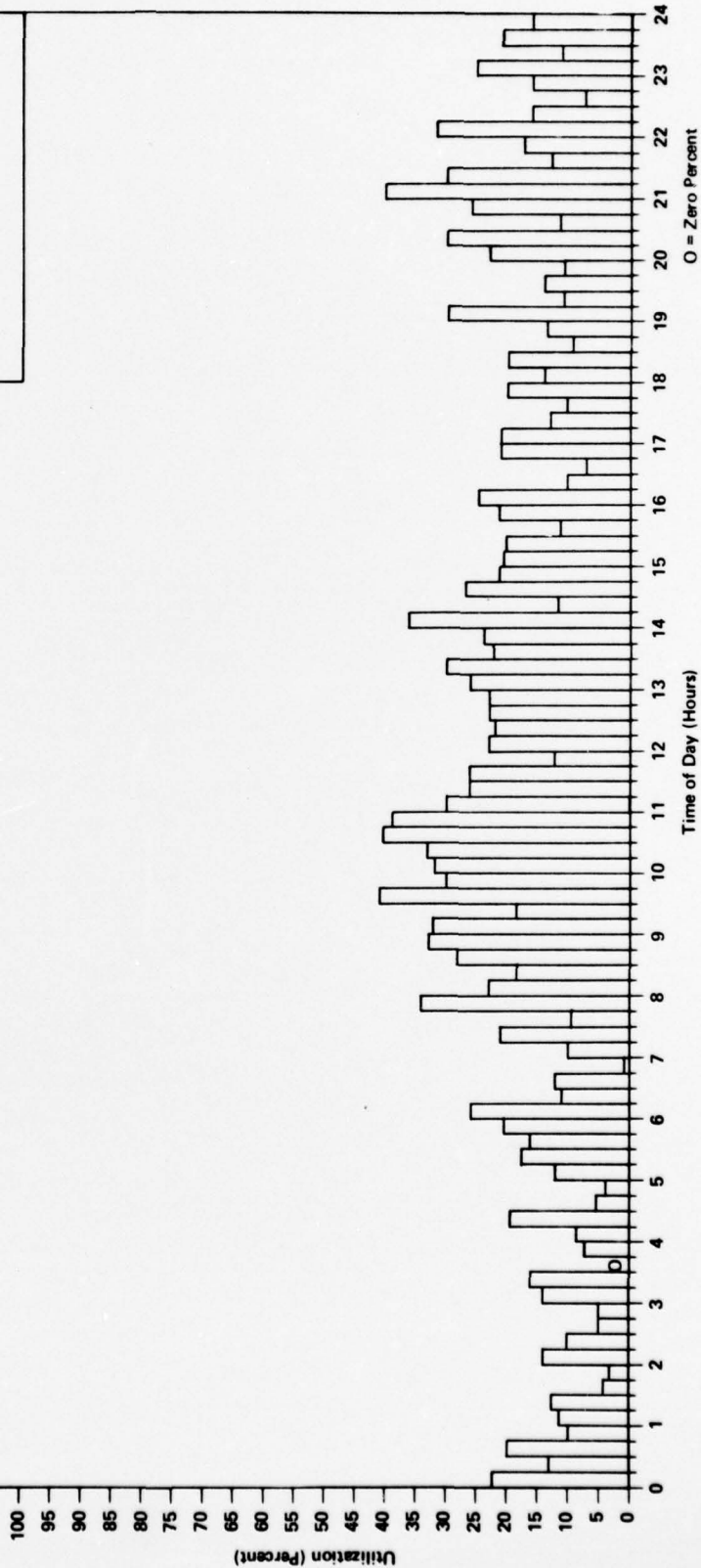
< = less than

COMMUNICATIONS MESSAGE ACTIVITY
 Channel 13
 Location: Delaware Bay Area
 Van Site: Philadelphia Naval Base
 Date: 10 April 1975
 Day: Thursday



COMMUNICATIONS CHANNEL
UTILIZATION

Channel 13
Location: Delaware Bay Area
Van Site: Philadelphia Naval Base
Date: 10 April 1975
Day: Thursday



**COMMUNICATIONS CHANNEL
EFFICIENCY**

Channel 13

Location: Delaware Bay Area

Van Site: Philadelphia Naval Base

Date: 10 April 1975

Day: Thursday

