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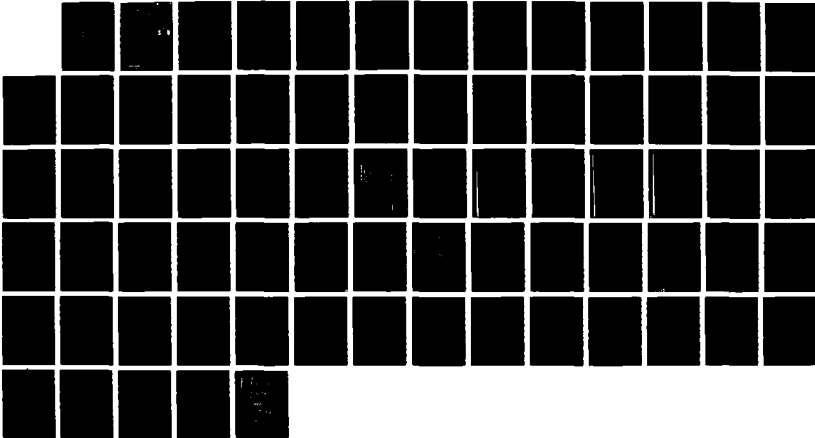
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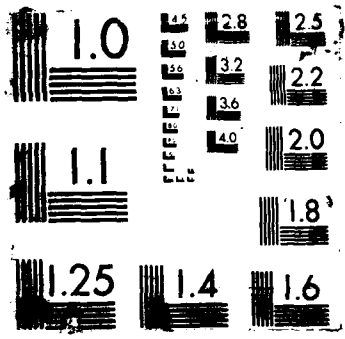
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THE ENVIRONMENTAL EVALUATION WORK GROUP FY 1979 STUDIES  
OF THE  
WINTER NAVIGATION DEMONSTRATION PROGRAM

EVALUATION OF BENTHIC DISLOCATION  
DUE TO PRESSURE WAVES INITIATED  
BY VESSEL PASSAGE IN THE ST. MARYS RIVER

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July 31, 1979

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) Shipping through ice creates pressure waves. Pressure waves can displace benthos. The object of this study was to determine if through 'hinge' cracks in the ice the quantitative and qualitative loss was significant to the total estimated benthic population at three St. Marys River sites sampled between January 26 and March 27, 1979. Benthic displacement was associated with vessel length, speed, channel distance, bottom contours of the river, ice thickness and benthic density. The study found that approximately 0.1% of the benthic population below the ice was displaced and concluded that at Coast Guard regulated vessel speed limits, little damage would occur to existing benthic populations as a result of displacement through surface ice 'hinge' cracks. <i>Keywords: dipterans, benthos, pressure waves, vessel passage</i>			
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## ABSTRACT

Ships navigating ice covered connecting channels in the Upper Great Lakes frequently reach a critical speed which creates a pressure fracture line near the shore. The sudden pressure release due to the fracture displaces water, sediments and incumbent benthos to the ice surface. The object of this study was to determine if the loss and environmental disruption was significant to the total estimated benthic population at selected sites in the St. Mary's River.

Three stations established on the St. Mary's River between Frechette (NE $\frac{1}{4}$  Sec. 22, T47N, R1E) and Six Mile Points (SE $\frac{1}{4}$  Sec. 26, T47N, R1E) were sampled during the winter of 1978-79. Sampling parameters included benthic, ice surface deposits and ice movement due to vessel passage. Twenty-four ships monitored provided 11 samples of which 5 contained benthic organisms.

## SUMMARY

The 1978-79 extended shipping season did not produce a significant loss of benthos to the ice surface. It was found that for a one meter length of crack approximately 10 organisms were displaced per vessel passage, or 0.1% of the existing benthic population below the sample sites.

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## OBJECTIVES

It has been noted that there is sediment deposition to surface ice through fracture lines that develop as a result of vessel movement through ice fields. This study was undertaken in an attempt to determine quantitatively and qualitatively the possible loss of benthos associated with this loss of sediment to surface ice.

Three near shore sites known to be affected by the pressure wave effect were chosen as sample locations for the study. Benthic displacement was evaluated in correlation with vessel length and speed and also the bottom contour and the distance from the channel the displacement occurs. Other experimental considerations include ice thickness, time or date, and the original benthic density, all of which may be important in determining the significance of the benthic displacement.

## INTRODUCTION

Previous Observations: On January 25, 1978, a group from the environmental section of the United States Corps of Engineers and representatives from the United States Fish and Wildlife Service met in Sault Ste. Marie, Michigan to witness firsthand the type of action that takes place in the ice field during vessel passages. These observations were later further substantiated by a group from CRREL that was working at Nine Mile Point, Sugar Island. It was the information gained from these observations that eventually led to the present research in benthic displacement with respect to winter vessel traffic.

Identified Zones of Concern: The identified zones of concern for this study all lie along the St. Mary's River between Three Mile Road and the North Neebish Channel. Zone 1 runs from Three Mile Road to Nine Mile Road along the mainland shore of the river. Zone 2 is at Nine Mile Point on Sugar Island and Zone 3 being the North Neebish Channel. These zones, as well as the actual sample site selections, were a concurrence of the contractors, i.e. the Great Lakes Fishery Research Laboratory (GLFL) and the Cold Regions Research and Experimental Laboratory (CRREL).

## METHODOLOGY

Three sample sites were chosen along the mainland side of the St. Mary's River between Three and Five Mile Roads (Figure 1). Site No. 1 (Riverview) was located at Riverview Marina approximately 6 meters off shore. Site No. 2 (Doran's) was in front of Dr. Gleason's home near Four Mile Road, approximately 1 meter off shore. Site No. 3 (Adam's) was one-half mile upstream from Six Mile Point, about 8 meters from shore. Location of the benthic surface sampling apparatus was dictated by the presence and position of pressure wave induced fracture lines (Figure 2 - 7).

In order to correctly evaluate the benthic displacement data other parameters that were closely linked to it had to be monitored and measured as well. One of these parameters being the pressure wave associated with vessel passage. The apparatus for recording these pressure waves was developed and constructed at the Lake Superior State College Aquatics Research Laboratory (Figure 8). A 3/4 inch iron rod ran through a hole in the ice and was embedded about 2 feet into the bottom. To this a writing instrument was attached on an arm of spring steel (to keep constant pressure against the recording drum). The recording was made using a modified Bird-type kymograph which was free to move with the ice sheet. A timer automatically ran the kymograph for a 12 minute (usually) interval during vessel passage.

It was found necessary to place a coil of heating cable around the inside of a 2 foot length of 6 inch diameter aluminum pipe and then place

## Methodology (Continued)

this into the hole surrounding the iron pipe. This was to prevent the hole from freezing up around the iron pipe and thus causing it to move with the ice sheet. A heat lamp was on constantly to help keep the equipment functioning properly despite the extremely cold conditions. All equipment was housed in a 4 foot by 4 foot portable canvas ice fishing shanty.

Following vessel passage recordings were properly calibrated by time (minutes) and vertical ice movement (centimeters). Titles and important observations were also recorded on the charts at this time.

The apparatus for ice surface sampling of displaced benthos was also developed at the Lake Superior State College Aquatics Research Lab (Figure 9). This basically consisted of a large plastic bag that was attached to a wooden frame. The frames were rectangular and enclosed on the top and both sides leaving the bottom and both ends open. These frames were constructed in three different sizes on the basis of frame mouth width. The three mouth widths used were 8, 10, and 16 cm respectively. From this point on, the ice surface benthic samplers will be referred to as simply benthic samplers.

After randomly locating the sample site along a 100 foot stretch of the fracture line the benthic samplers were set up as follows. A large depression was chipped out approximately 15 cm from the crack. The wooden sampler frame was then placed perpendicular to the crack such that it rested at the edge of the depression and extended slightly over the edge of the crack. Two wire test tube racks were then placed

## Methodology (Continued)

in the collecting bag to keep accumulating snow from collapsing the bag and preventing displaced water from entering. The bag was then carefully placed into the depression and its mouth then attached to the frame by a strong rubber band. Slush was packed along the side of the frame as a sealant to insure that all displaced water entering the frame mouth would be funnelled into the collecting bag. The benthic samplers were found to effectively collect about 90 to 95 percent of the displaced water.

Immediately following vessel passage the samplers were checked to see if a sample had been obtained. Those containing samples were placed in a second bag and taken to the laboratory for later study. Empty samplers were collected.

At the lab samples were filtered through a suction filter and the volume of water was then measured and recorded. Filter papers were then scanned under a dissecting scope (15x magnification) for any benthic organisms present. Organisms found were placed in 10 percent formalin and later were keyed and identified.

Bottom samples were taken at all sample locations in order to form a basis of comparison for evaluating later benthic displacement data. Riverview was sampled on January 24, Doran's on January 25, and Adam's on February 15.

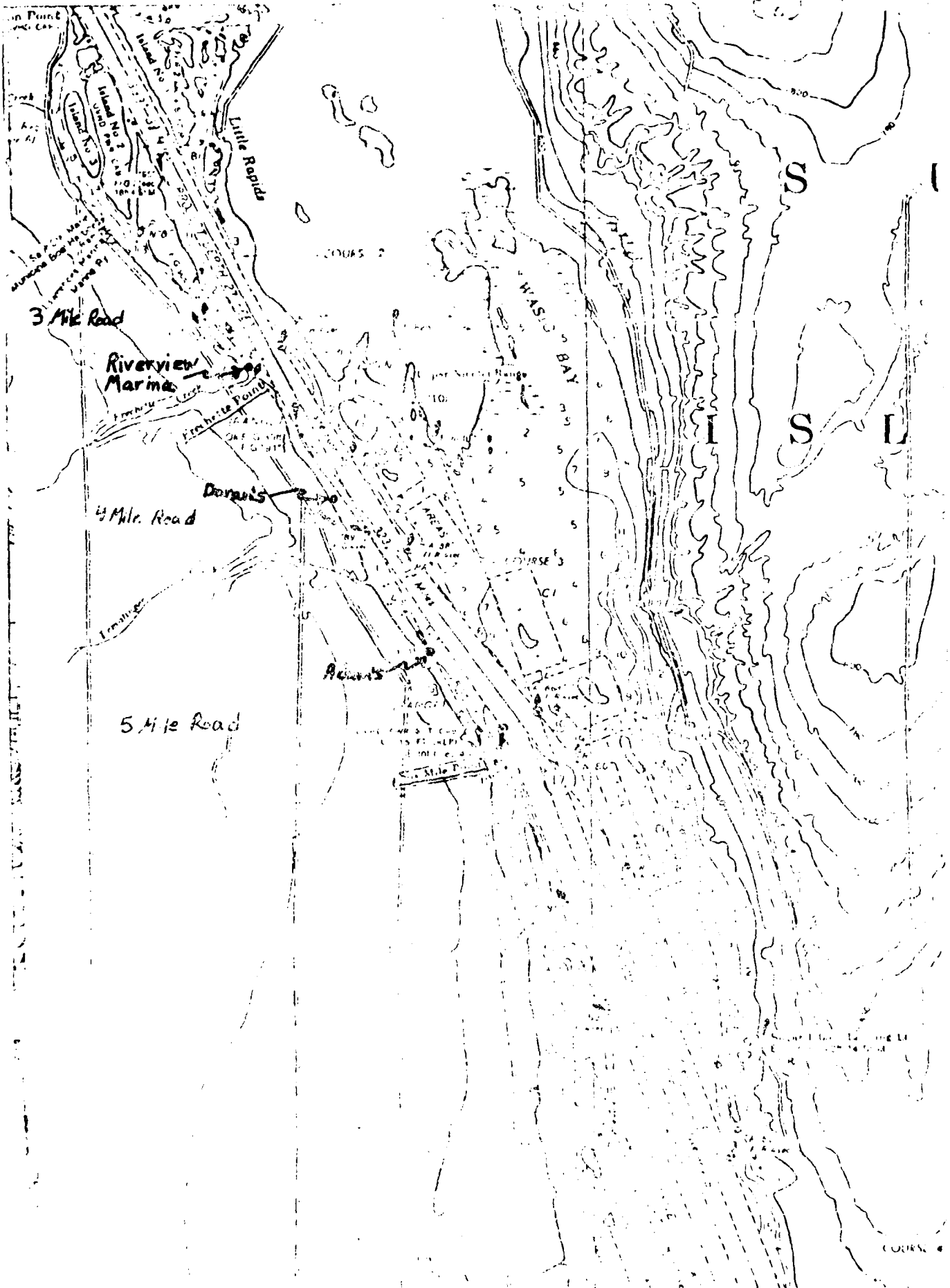
A "Dinky" power auger was used to drill four holes approximating the corners of a square. The ice in between was spudged out and the freed chunk removed. Three samples were then taken from a four foot square area. An Ekman bottom dredge was used to obtain the samples.

Methodology (Continued)

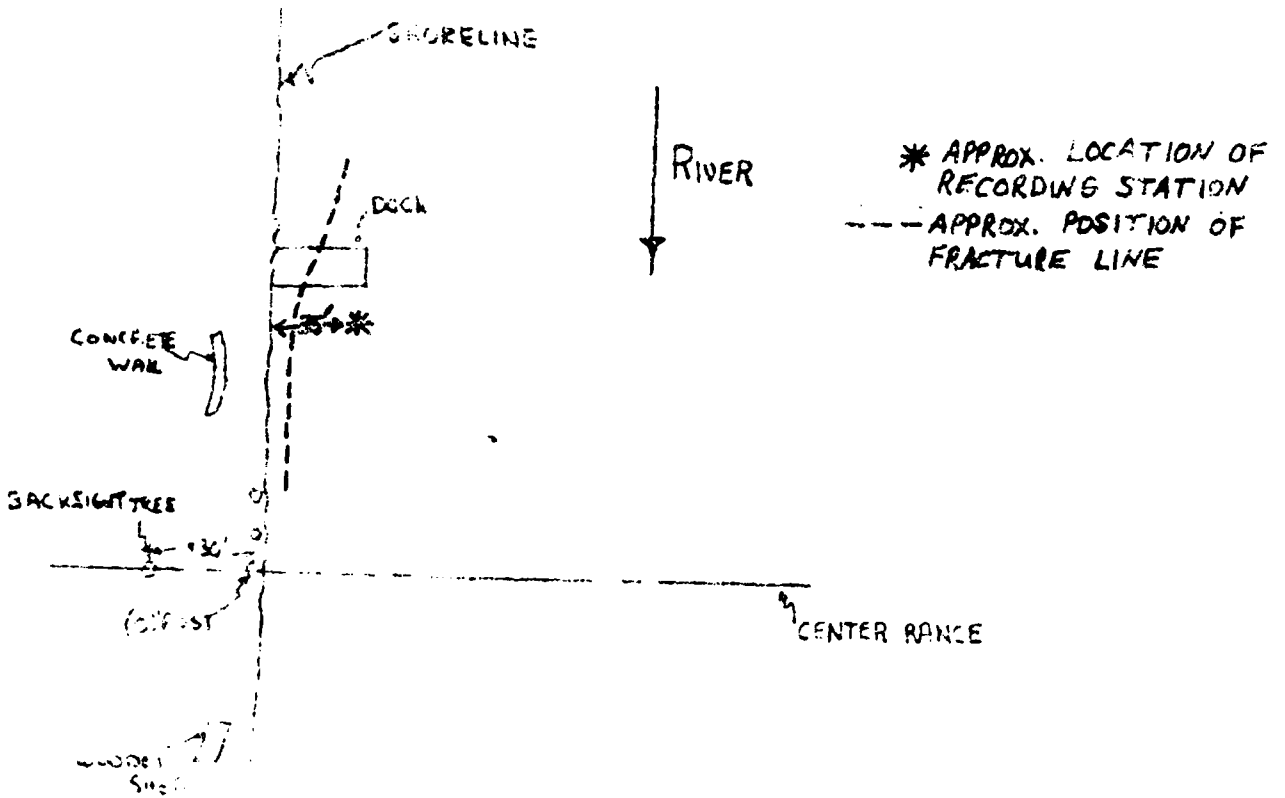
Samples were rinsed free of mud and sediments and placed into jars.

Organisms were later identified, counted and recorded. Specimens were preserved in 10 percent formalin solutions.

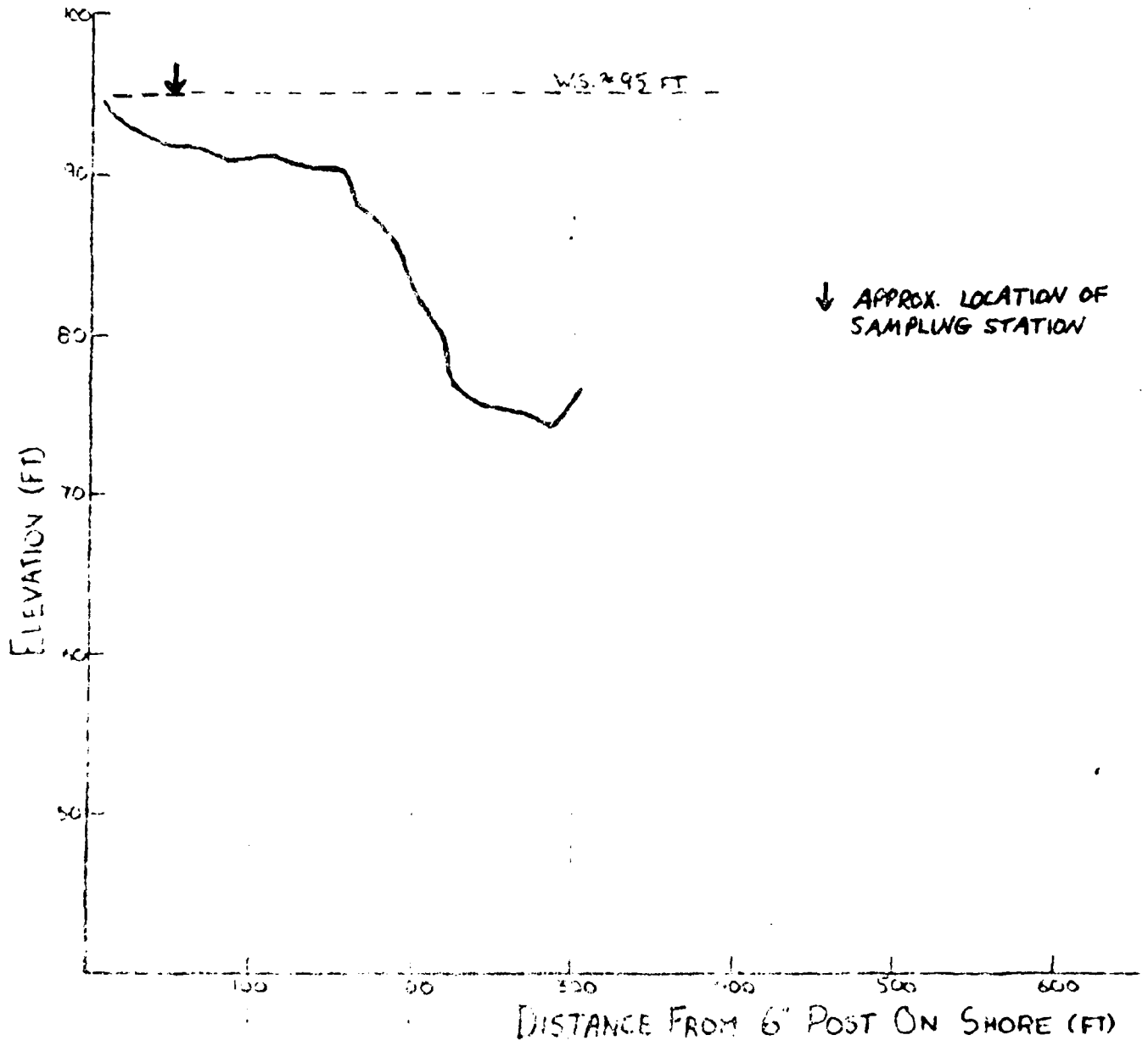
EXAMPLE SITE LOCATIONS  
Figure 1



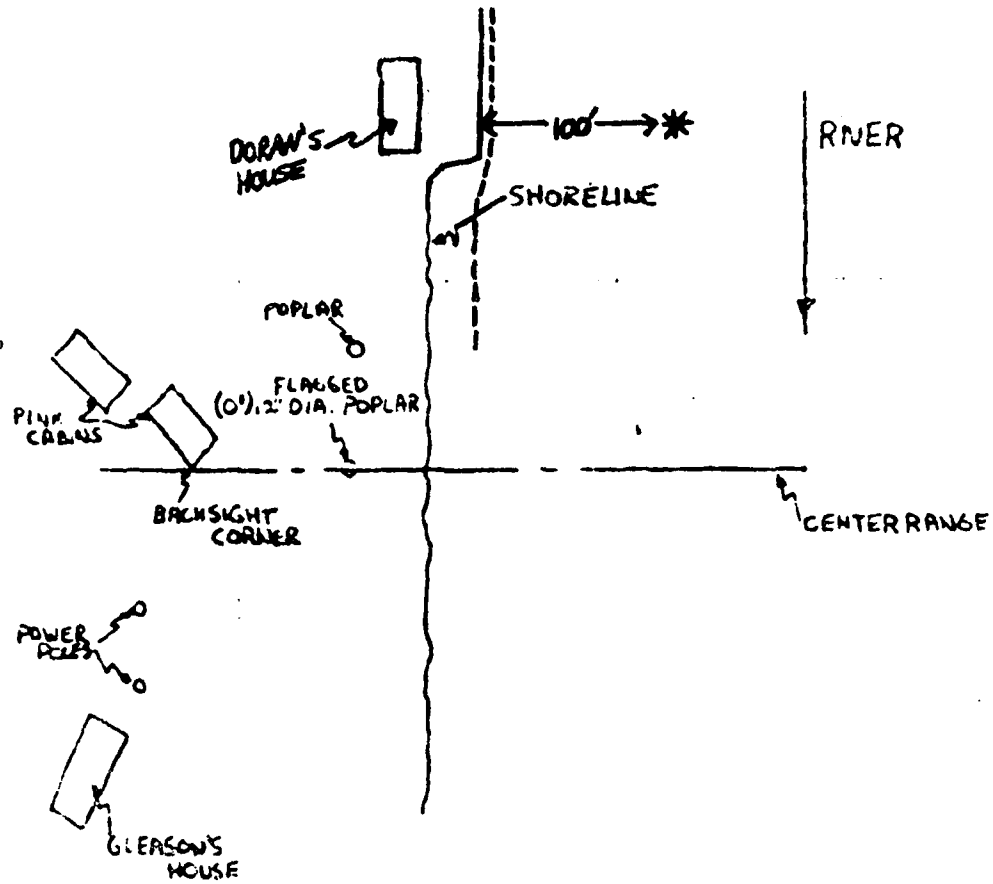
RIVERVIEW CENTER RANGE  
Figure 2



RIVERVIEW CENTER RANGE PROFILE  
Figure 3

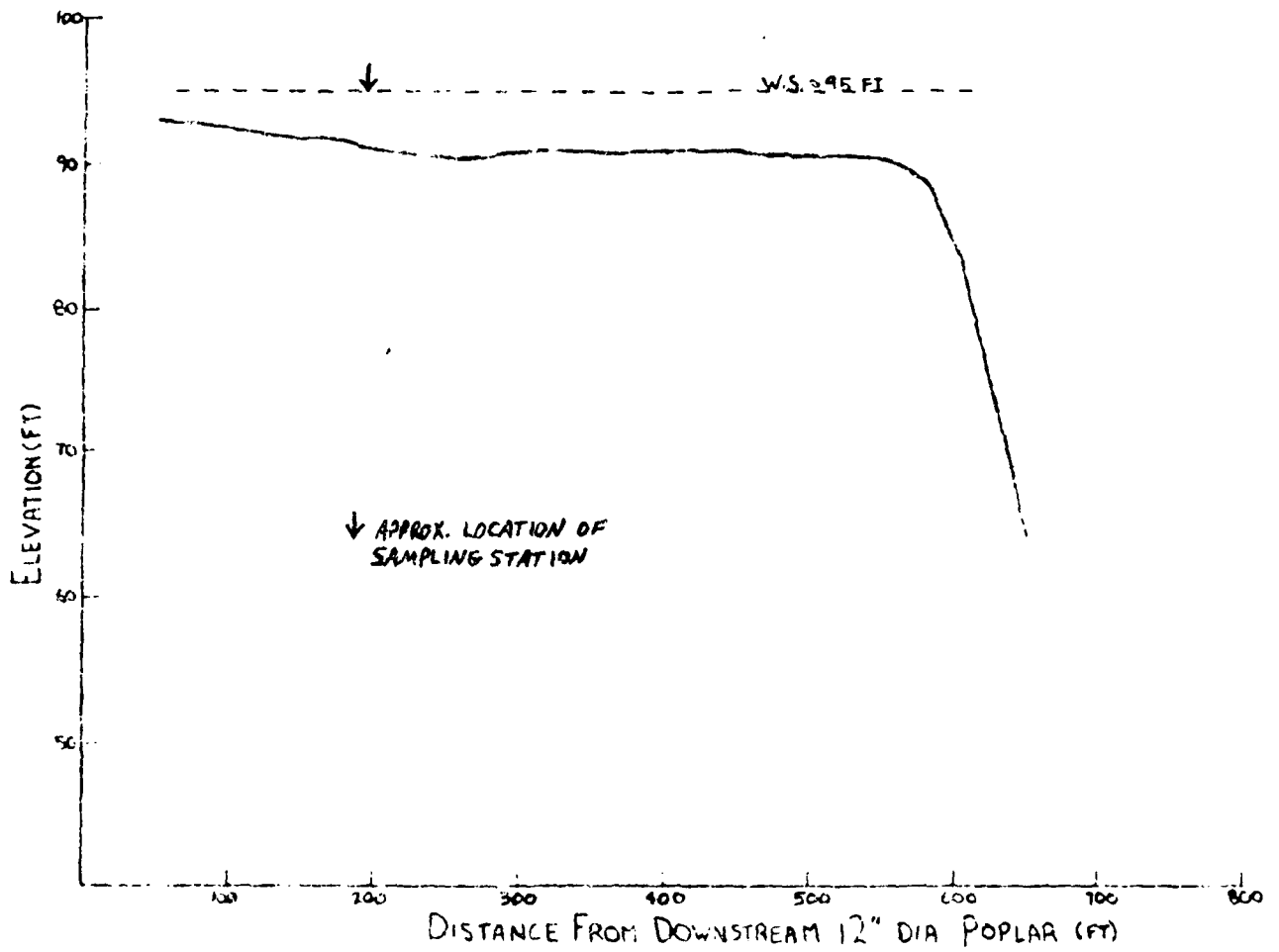


DORAN'S CENTER RANGE  
Figure 4

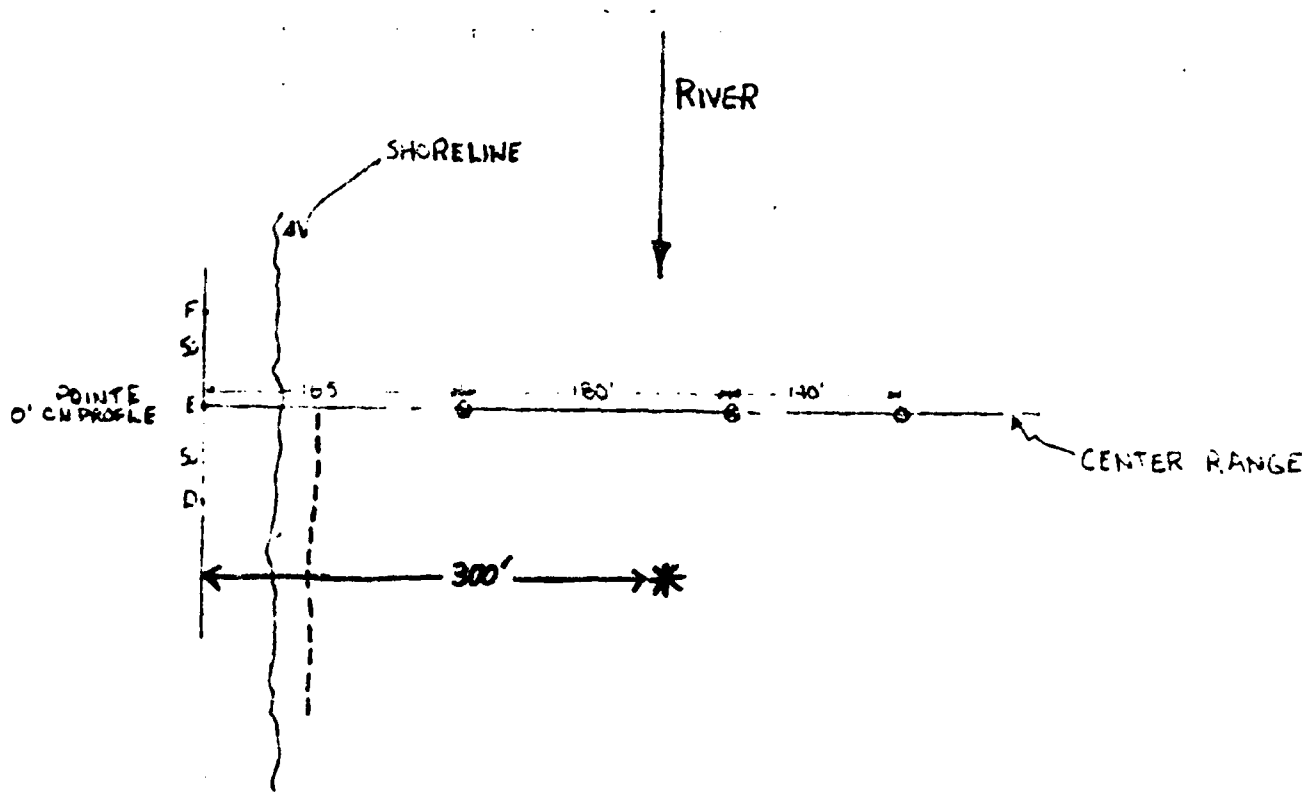


\* APPROX. LOCATION OF  
RECORDING STATION  
--- APPROX. POSITION OF  
FRACTURE LINE

DORAN'S CENTER RANGE PROFILE  
Figure 5

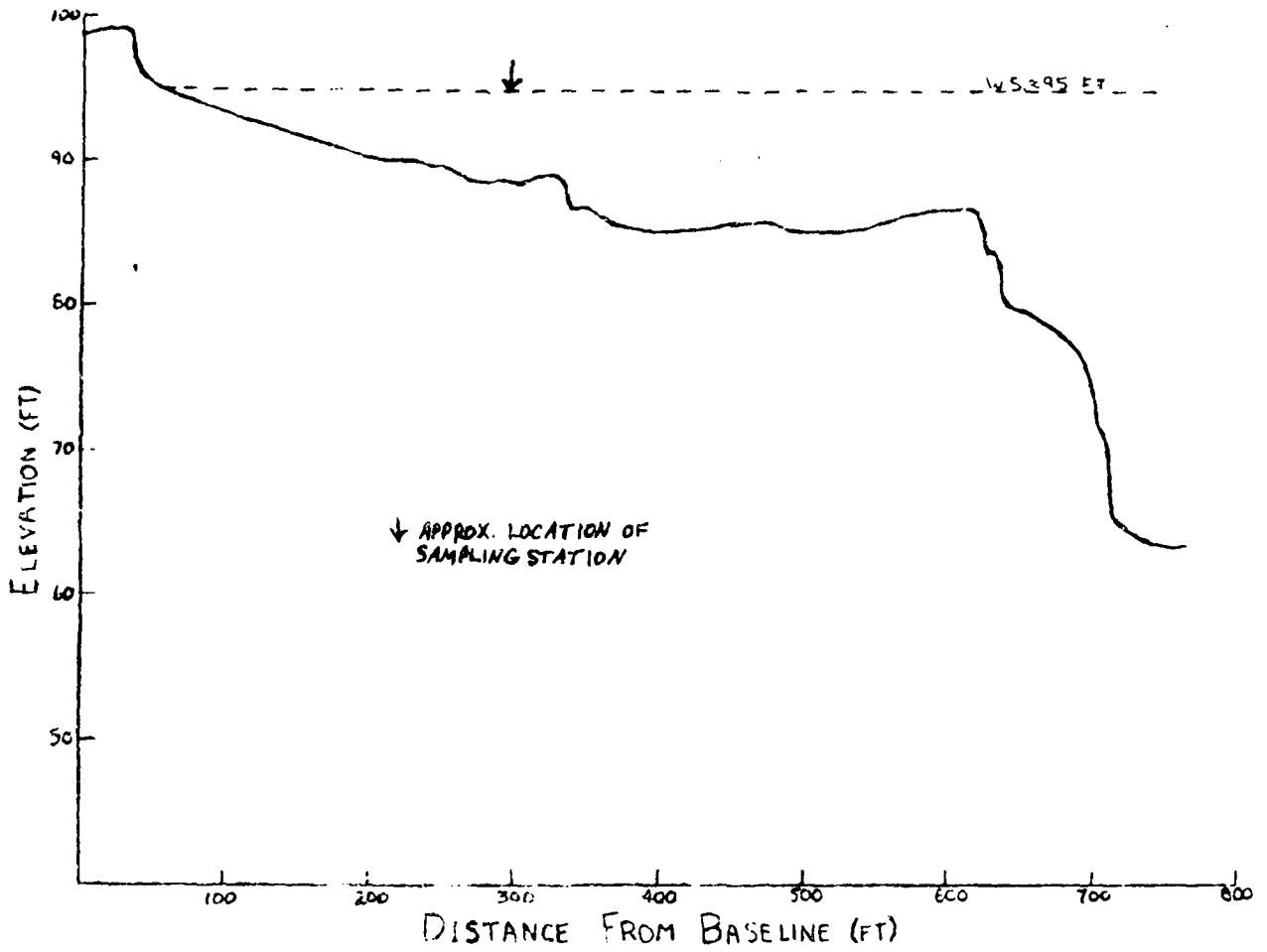


ADAM'S CENTER RANGE  
Figure 6



- ⊙ APPROX. LOCATION OF BENTHIC SAMPLING
- \* APPROX. LOCATION OF RECORDING STATION
- APPROX. POSITION OF FRACTURE LINE

ADAM'S CENTER RANGE PROFILE  
Figure 7



VESSEL PRESSURE WAVE RECORDING APPARATUS  
Figure 8

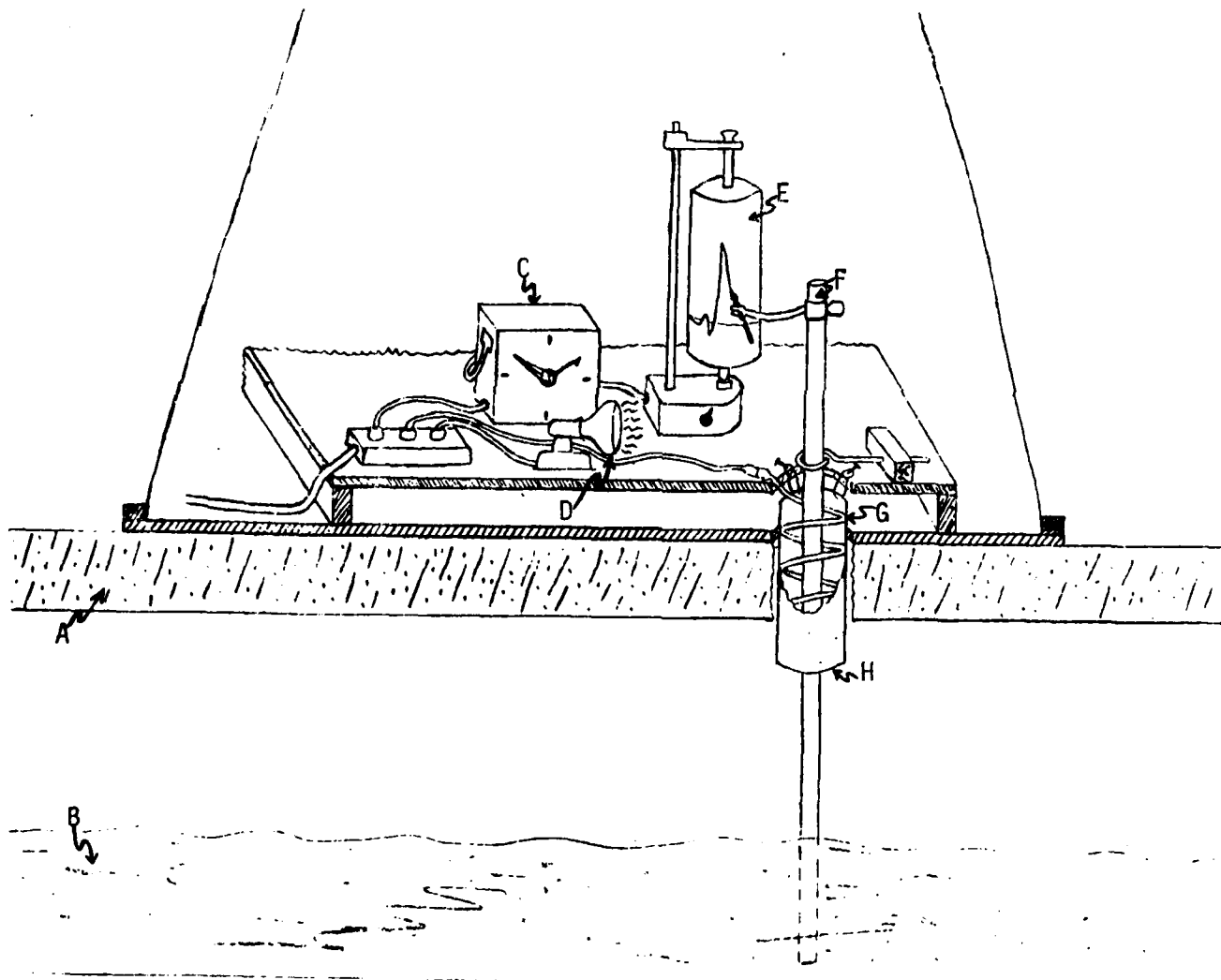
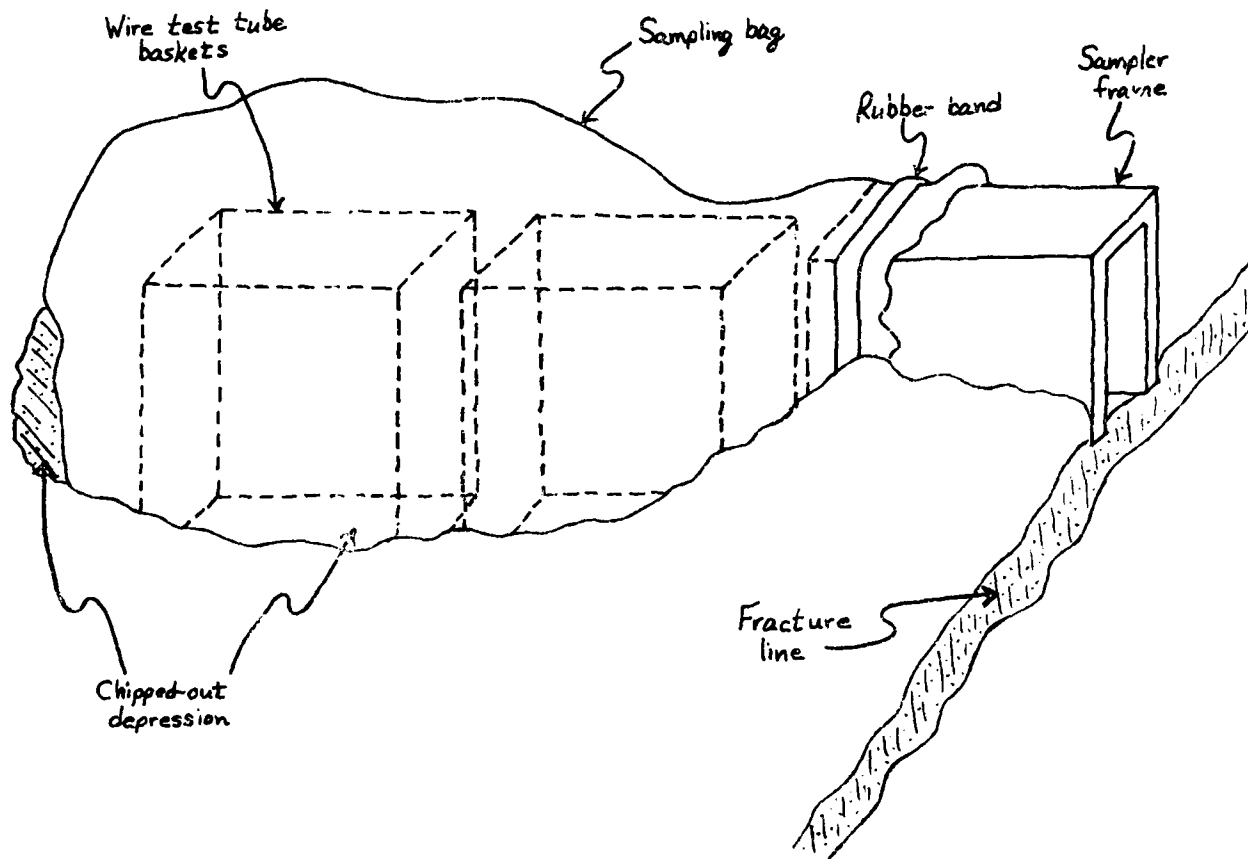


Figure 8 - A) ice sheet; B) bottom; C) timer; D) heat lamp; E) kymograph;  
F) iron pipe with attached writing instrument; G) heating cable;  
H) protective sleeve

SURFACE SAMPLING APPARATUS  
Figure 9



## ANALYSIS OF DATA

Ice movement was monitored during vessel passages from January 26 to March 27, 1979 as part of the benthic displacement study. During this time vertical ice movement values were found to range from 2.8 cm to 72.5 cm, depending on vessel length, speed and other conditions (Table 1). Crack samples were also taken during this time. Out of the twenty samples taken there were only five which contained benthic organisms and these correspond with the five largest vertical ice displacement values that were recorded. These five samples resulted from 3 vessel passages, since at times there were 2 different size samplers in place for each vessel passage. There appears to be a correlation between benthic loss to surface ice and vertical ice displacement, however this is only at extreme and maximum values. With reference to winter navigation it appears that under "normal" conditions and at regulated vessel speeds (i.e. the Coast Guard vessel speed limits) there would be little damage to existing benthic populations as a result of displacement to surface ice due to winter shipping.

In general it was found that for vessels of the same length and traveling at the same rate of speed, an upbound vessel will cause much more vertical ice displacement than a downbound one will. Two of the three successful events producing crack samples that contained benthic organisms were from upbound vessels and were also maximum ice displacement values (all greater than 64 cm vertical displacement). The other one was from a downbound vessel with a vertical displacement value of

## Analysis of Data (Continued)

71.2 cm. There was only one vessel with a vertical displacement value greater than 64 cm for which there were no benthic organisms present in its corresponding sample (Arthur M. Anderson, upbound, March 27). All samples associated with vertical ice displacement values less than 64 cm contained no benthic organisms (Table 2).

Bottom sample data served as an indicator of relative abundance of benthic organisms. It was used as a guideline in evaluating the crack sample data (Appendix B and C). By far the most abundant of the organisms found in the bottom samples were snails (Gastropoda), which made up 45% of all samples. The majority of the rest of the sample was composed of Diptera (17.4%), Annelida (17.3%), and Pelecypoda (12.4%). All other benthic organisms combined made up the remaining 8% (Table 3).

Crack sample data was taken from February 16 through March 27. There were 20 attempted samplings during this period, of which 10 of them produced crack samples. Of these there were only five that contained benthic organisms. The most abundantly occurring organisms were Dipterans which accounted for 75% of the organisms displaced, Annelida made up 15%, and Ostracods 10%. The most organisms collected in one sampler was 7 (5 Dipterans and 2 Annelids) on March 27 from the Phillip R. Clark's passage.

From February 16 through March 7 there was very little traffic due to extremely cold conditions and the resulting heavy ice build up (Figure 10). Following this there was a slight thaw for the next 10 days. Then

## Analysis of Data (Continued)

on the evening of March 18 the passages of the Cason J. Callaway and Roger Blough completely shattered the ice fields at Riverview and Doran's and had only a slight impact at Adam's. The field was broken into many large ice floes ranging in size from a few feet across to as much as 25 feet across in some cases. There was a great deal of sediment deposition on surface ice and in some places large clumps of aquatic vegetation were deposited at the edges of fractures as they shifted. These clumps were taken to the lab and carefully analyzed, however they were found to be almost completely devoid of benthic organisms. Though the break up was quite dynamic in the physical sense, there was very little apparent affect on the benthic communities involved, with regard to displacement to surface ice.

From the bottom sample data the average benthic density was found to be 9,593 organisms per square meter. Of the 20 attempted samplings there were a total of 21 organisms collected, or about one organism per vessel passage. Further calculations show that for a one meter length of crack there would be approximately 10 organisms displaced per vessel passage, or about 0.1% of the existing benthic population.

VERTICAL ICE DISPLACEMENT DATA

Table 1

<u>Vessel Description</u>	<u>Direction</u>	(cm) <u>Ice Depth</u>	(cm) <u>Vertical Ice Displacement</u>	(sec.) <u>Recovery Time</u>
<u>0-400 Ft. (0-118.5 m)</u>				
<u>5-10 mph (8-16 kph)</u>				
C. G. C. Mackinaw	Upbound	33	25	36
C. G. C. Mackinaw	Upbound	35	11.2	90
<u>Over 10 mph (16 kph)</u>				
C.G.C. Katamai Bay	Upbound	25	4.2	24
<u>400-700 Ft. (118.5-207.4 m)</u>				
<u>0-5 mph (0-8 kph)</u>				
Hudson Transport	Downbound	33	2.8	30
<u>5-10 mph (8-16 kph)</u>				
Enders M. Vorhees	Upbound	25	14.7	42
Doan Transport	Upbound	33	19	54
Leon Fraser	Downbound	33	14.5	36
John G. Munson	Upbound	35	63	144
Imperial St. Clair	Upbound	46	48	156
Imperial St. Clair	Downbound	46	15.3	18
Imperial St. Clair	Upbound	38	7.5	78
Arthur M. Anderson	Downbound	42	72.5	48
Arthur M. Anderson	Upbound	44	19.7	42
John G. Munson	Upbound	44	26.3	54
<u>Over 10 mph (16 kph)</u>				
Imperial St. Clair	Upbound	40	23.5	72
<u>700-1000 Ft. (207.4-296.3 m)</u>				
<u>0-5 mph (0-118.5 kph)</u>				
Edwin H. Gott	Upbound	35	20.8	57
<u>5-10 mph (8-16 kph)</u>				
Prosper Isle	Downbound	33	12.8	48
Philip R. Clark	Upbound	35	24	108
Carson J. Callaway	Upbound	35	60	174
Roger Blount	Downbound	44	12.2	72
Carson J. Callaway	Downbound	44	11.2	34
<u>Over 10 mph (16 kph)</u>				
Carson J. Callaway	Downbound	33	26.2	24
Philip R. Clark	Downbound	44	7.2	30
Philip R. Clark	Upbound	44	47.6	66

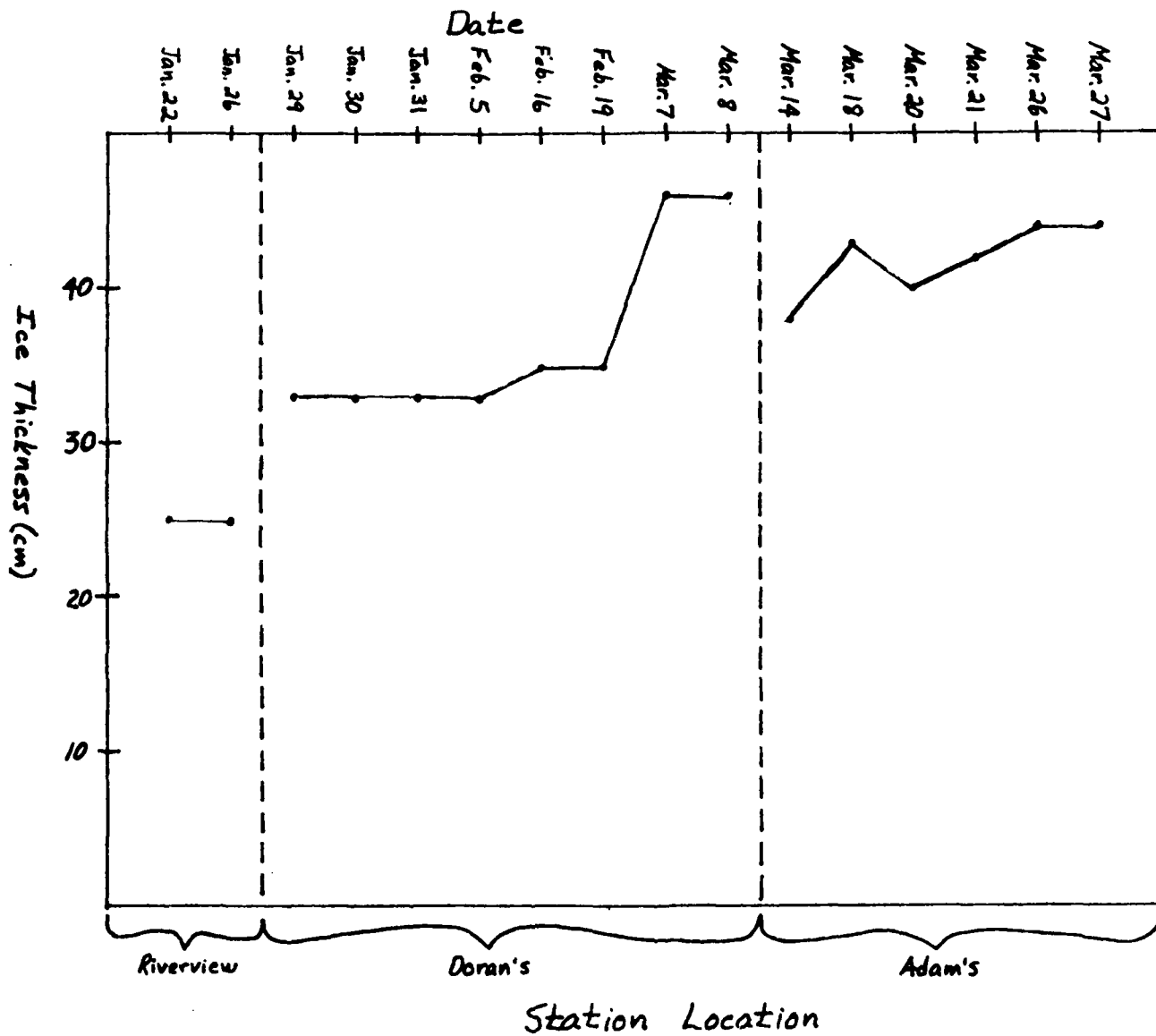
BENTHIC PERCENT COMPOSITION OF BOTTOM SAMPLES  
Table 2

<u>DATE</u>	<u>LOCATION</u>	<u>VESSEL</u>	<u>DIRECTION</u>	<u>(cm) SAMPLER SIZE</u>	<u>BENTHIC ORGANISMS DISPLACED</u>
2-16	Doran's	Phillip R. Clark	Upbound	16	Diptera Chironomidae Orthoclaadiinae (2) Tanypodinae (3) Heleidae (1)
3-7	Doran's	Imperial St. Clair	Upbound	16	None
3-7	Doran's	Imperial St. Clair	Upbound	8	None
3-8	Doran's	Imperial St. Clair	Downbound	16	None
3-8	Doran's	Imperial St. Clair	Downbound	8	None
3-14	Adam's	Imperial St. Clair	Upbound	16	None
3-18	Doran's	Roger Blough	Upbound	10	Diptera Chironomidae Chironominae (1) Orthoclaadiinae (2) Tanypodinae (1)
3-18	Adam's	Roger Blough	Upbound	16	None
3-18	Adam's	Roger Blough	Upbound	8	Diptera Chironomidae Chironeminae (1) Annelida (1)
3-20	Adam's	Imperial St. Clair	Upbound	16	None
3-20	Adam's	Imperial St. Clair	Upbound	8	None
3-21	Adam's	Arthur M. Anderson	Downbound	16	None
3-21	Adam's	Arthur M. Anderson	Downbound	8	None
3-21	Adam's	Phillip R. Clark	Downbound	16	Ostracoda (2)
3-21	Adam's	Phillip R. Clark	Downbound	8	Annelida (2) Diptera Chironomidae Orthoclaadiinae (3) Tanypodinae (2)
3-26	Adam's	Roger Blough	Downbound	10	None
3-26	Adam's	Cason J. Callaway	Downbound	10	None
3-27	Adam's	Phillip R. Clark	Upbound	10	None
3-27	Adam's	Arthur M. Anderson	Upbound	8	None
3-27	Adam's	John G. Munson	Upbound	8	None

DISTRIBUTION IN PERCENT  
OF BENTHOS AT SAMPLE STATIONS  
TABLE 3

<u>Order</u>	<u>Riverview</u>	<u>Doran's</u>	<u>Adam's</u>	<u>Mean For All Stations</u>
GASTROPODA	49.2	57.8	28.2	45.1
DIPTERA	8.1	17.7	26.5	17.4
ANNELIDA	22.3	10.9	18.8	17.3
PELECYPODA	10.9	7.7	18.7	12.4
AMPHIPODA	2.4	2.4	0.3	1.7
HYDRACARINA	2.7	1.8	0.3	1.6
TRICHOPTERA	1.9	0.9	1.6	1.5
EPHEMEROPTERA	1.9	0.3	2.1	1.4
NEMATODA	0.2	0.3	1.9	0.9
ISOPODA	0.3	0.1	1.6	0.7
MEGALOPTERA	0.0	0.1	0.0	0.03

ICE THICKNESS DURING SAMPLING PERIOD  
Figure 10



## CONCLUSIONS AND RECOMMENDATIONS

The results of the investigation conducted during the winter of 1978-79 on the effects of pressure wave displacement of benthic organisms to the ice surface and subsequently lost to the environment proved to be insignificant. Observations during past winters (1976-77 and 1977-78) would indicate that the winter of 1978-79 was not characteristic as it relates to the frequency of relief cracks and the subsequent ice surface contamination by sediments and benthos.

The minimal affect experienced during 1978-79 can be attributed to the decrease in shipping activity (number of vessels per week), the mode of ice breaking (Katamai Bay vs. the Mackinaw) and the rate and type of ice formation due to the winter. If the frequency of activity by upbound and downbound vessels had been maintained at 4+ passages per week and if the Mackinaw had been used for ice breaking, the previously observed shore ice - sheet ice junctures would have maintained the open fractures through which the benthic dislocation affect had been observed in the past. The degree in frequency coupled with the extremely cold periods of extended freezing allowed interstitial ice to become strong enough that only when vessels reached critical speeds did new fractures form. Early winter fractures occurred very close to shore and produced only water and some fine sands. These reaches of the littoral zone are traditionally low or devoid of benthic representatives. It is not until the shore ice has moved out to a depth of 1 to 1.5 meters that aquatic invertebrates and vertebrates appear on the ice surface. The investigation carried out by Lake Superior State College would indicate that ice surface loss under present conditions of

## Conclusions and Recommendations (Continued)

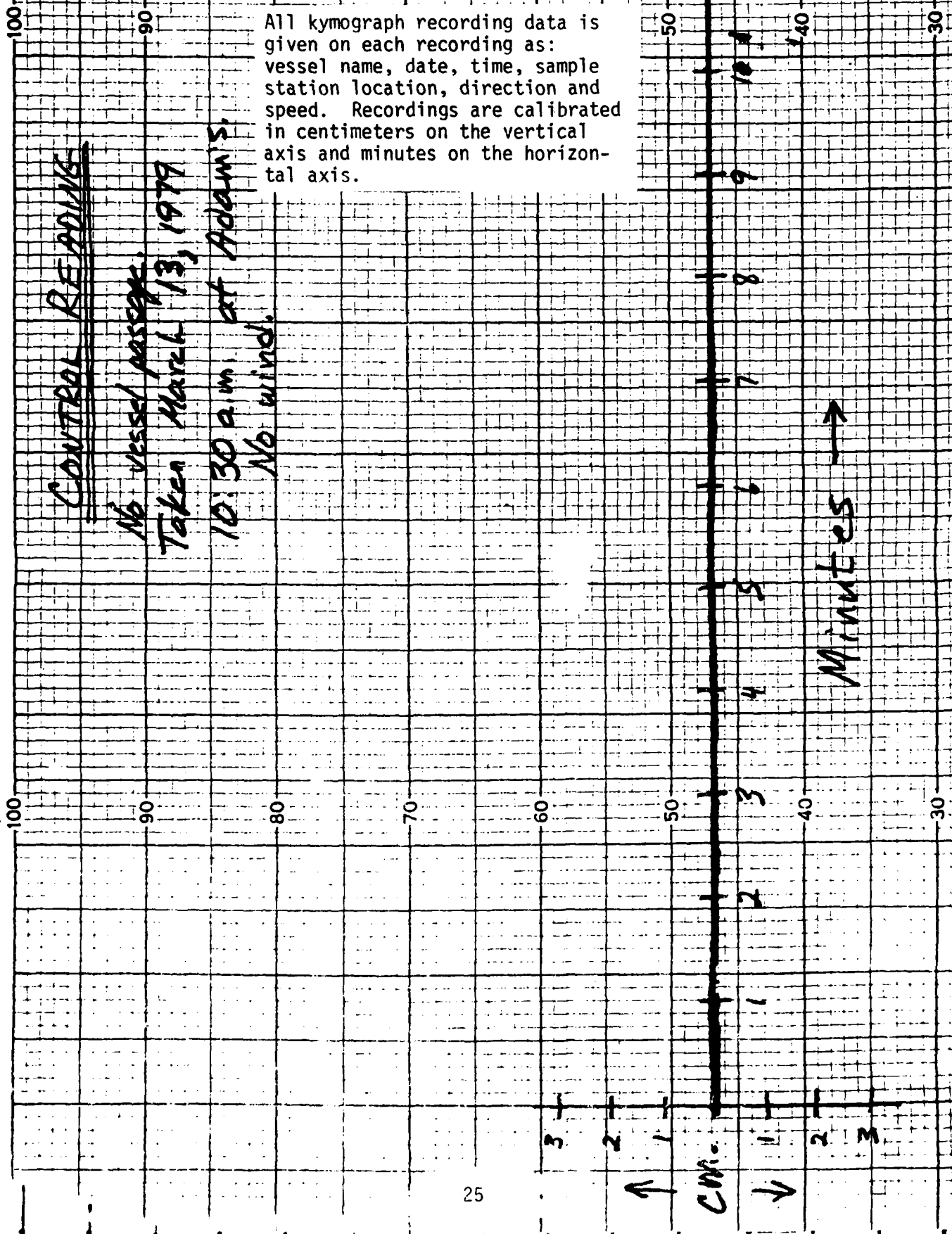
operation (1978-79) does not merit further study and that the losses to the system are insignificant in comparison to the annual mortality associated with the area studied. This recommendation does not exclude the possibility that subsurface dislocation and disruption of the benthic ecology does exist.

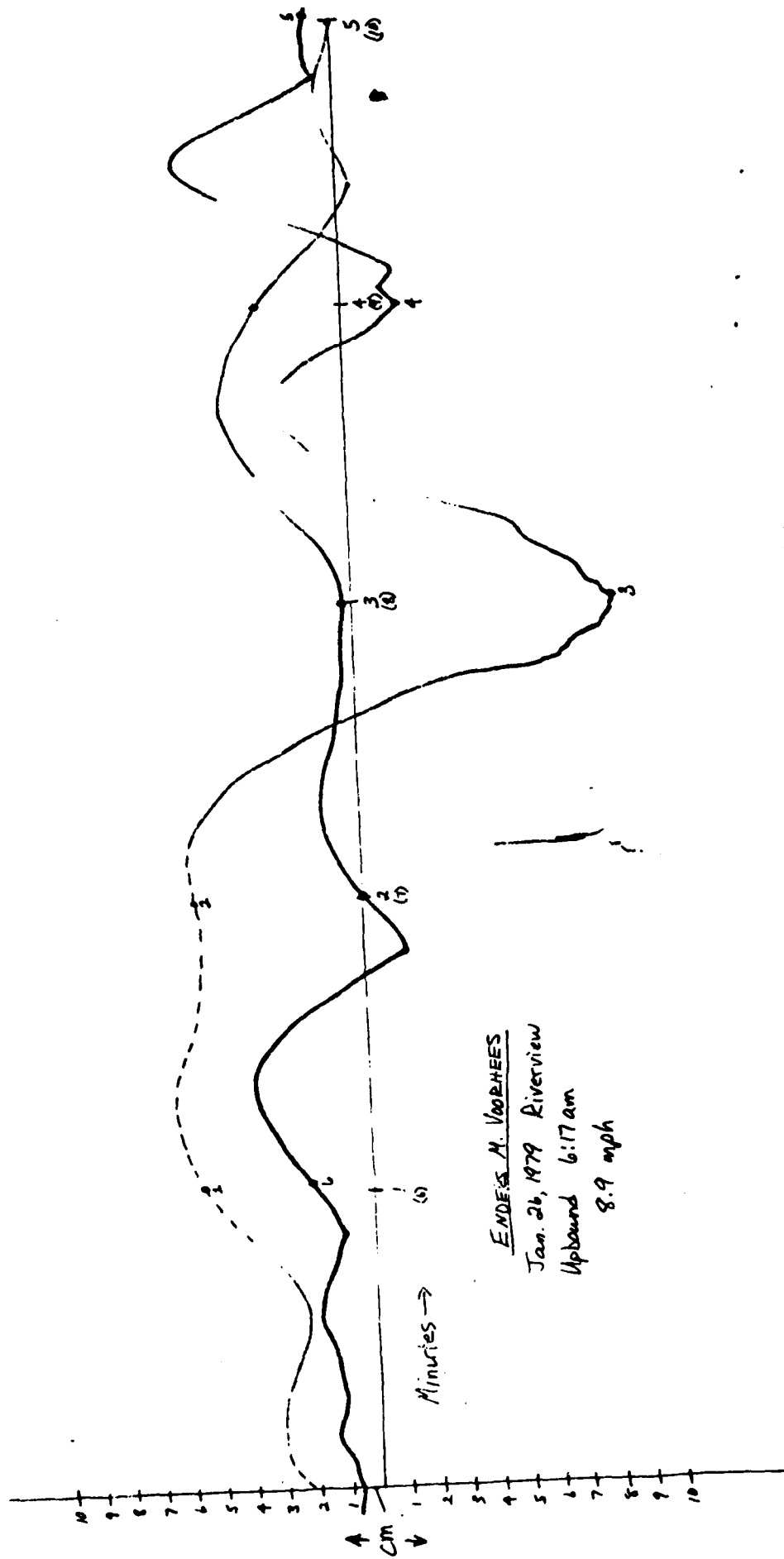
Appendix A: KYMOGRAPH RECORDINGS

All kymograph recording data is given on each recording as: vessel name, date, time, sample station location, direction and speed. Recordings are calibrated in centimeters on the vertical axis and minutes on the horizontal axis.

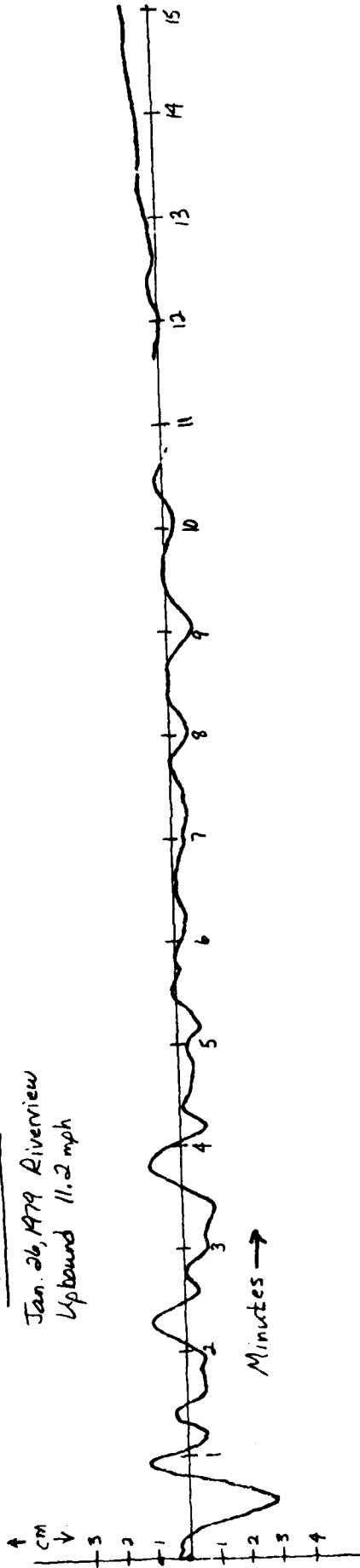
CENTRAL READINGS

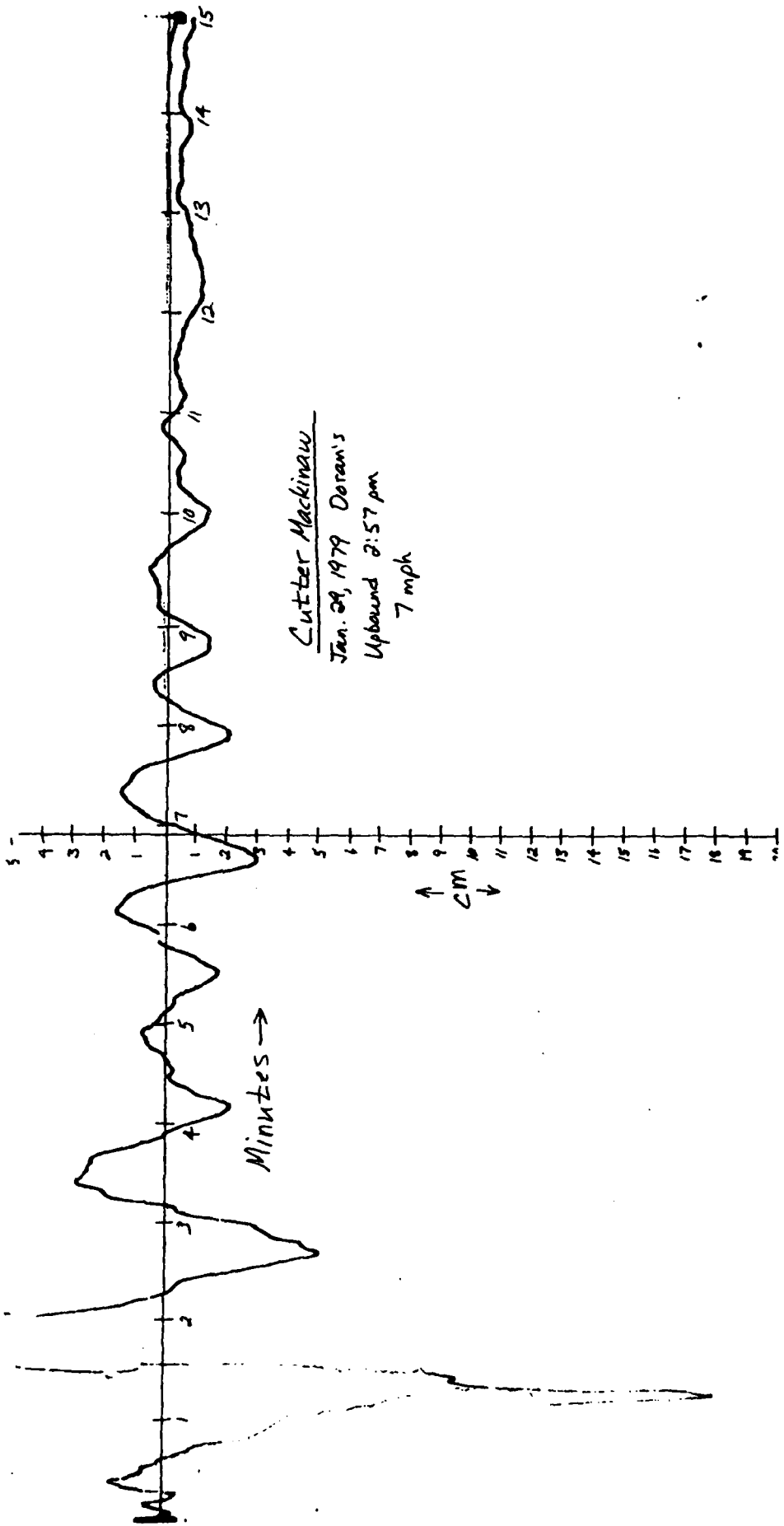
No vessel present.  
 Taken March 13, 1979  
 10:30 a.m. at Adams S.  
 No wind.

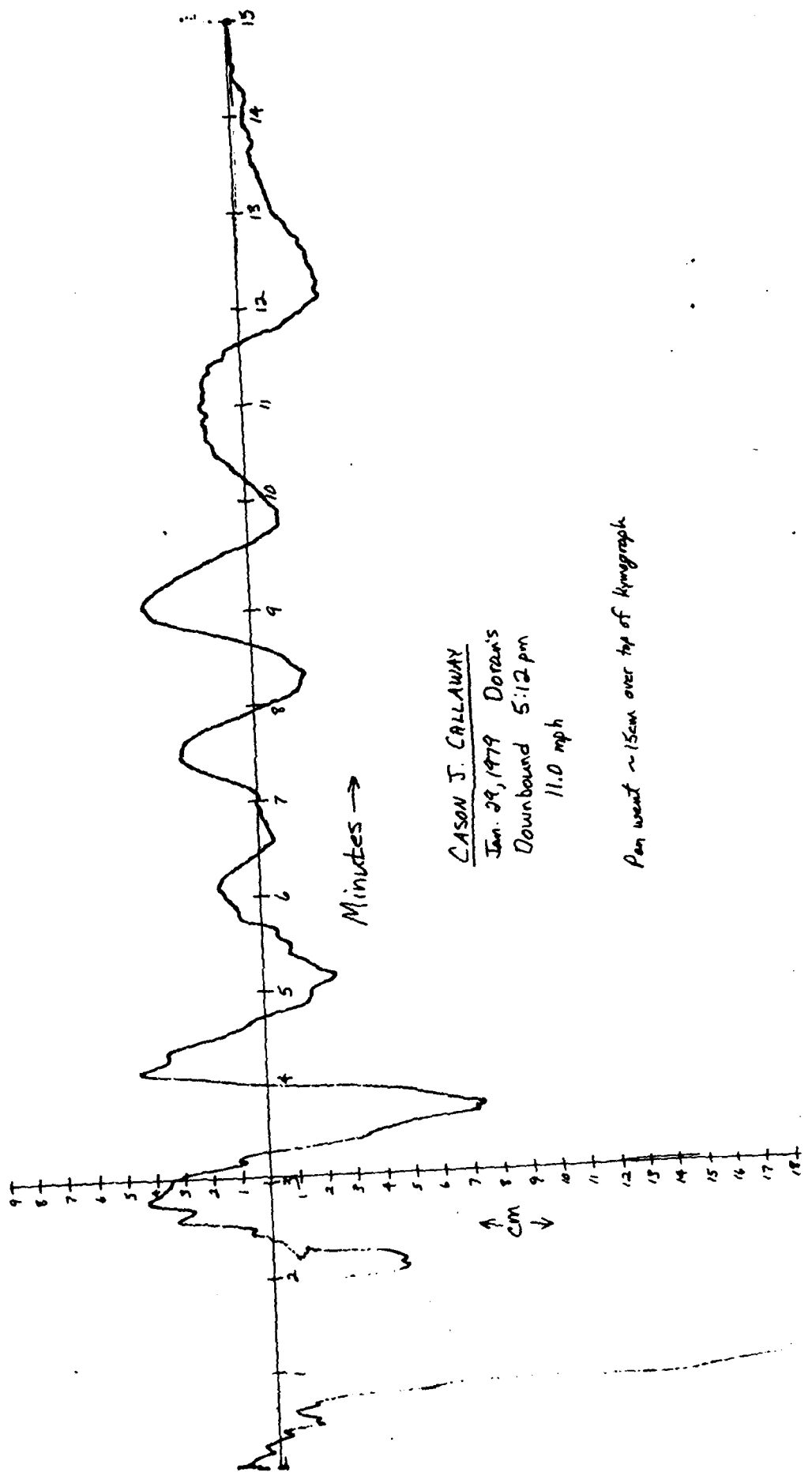




Katamai Bay  
Jan. 26, 1979 Riverview  
Upbound 11.2 mph



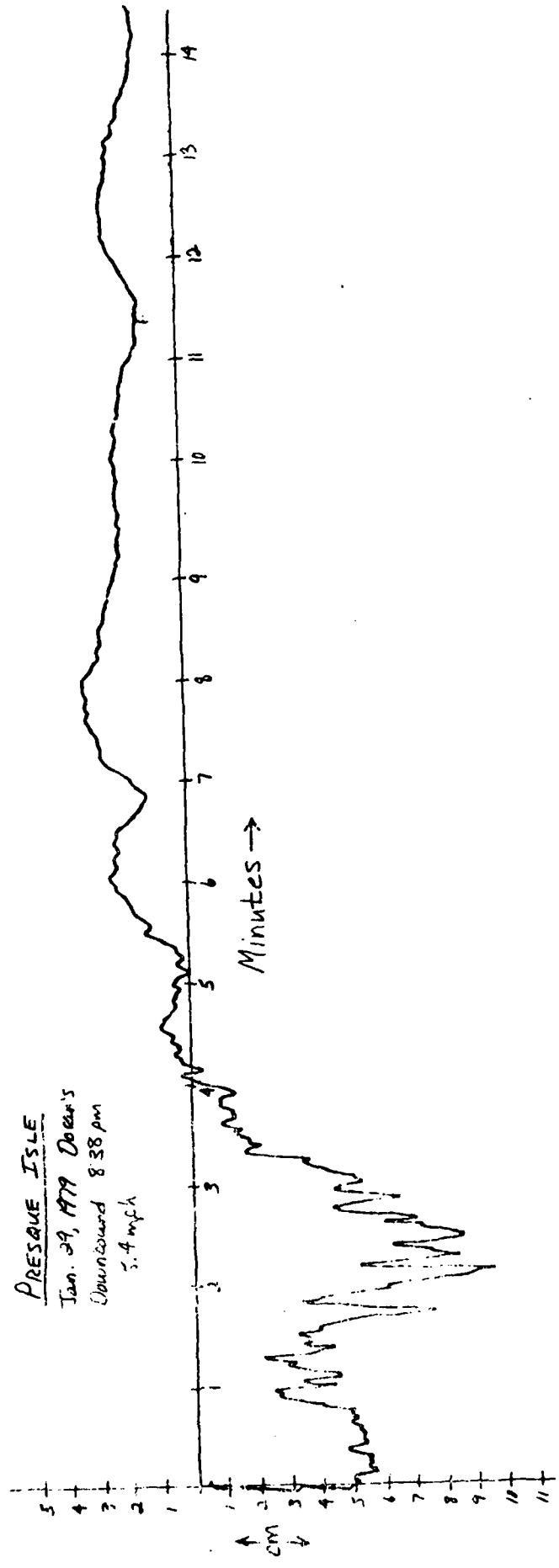




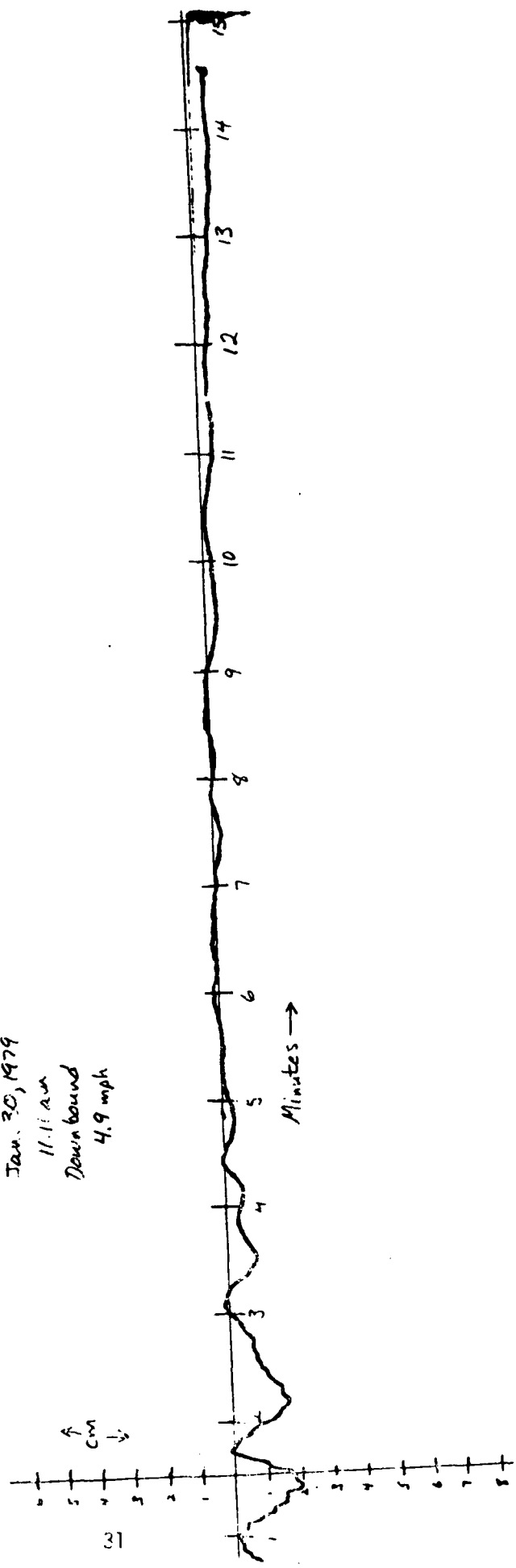
CASON J. CALLAWAY  
 Jan. 29, 1979 Doran's  
 Downbound 5:12 pm  
 11.0 mph

Pen went ~15cm over top of kymograph

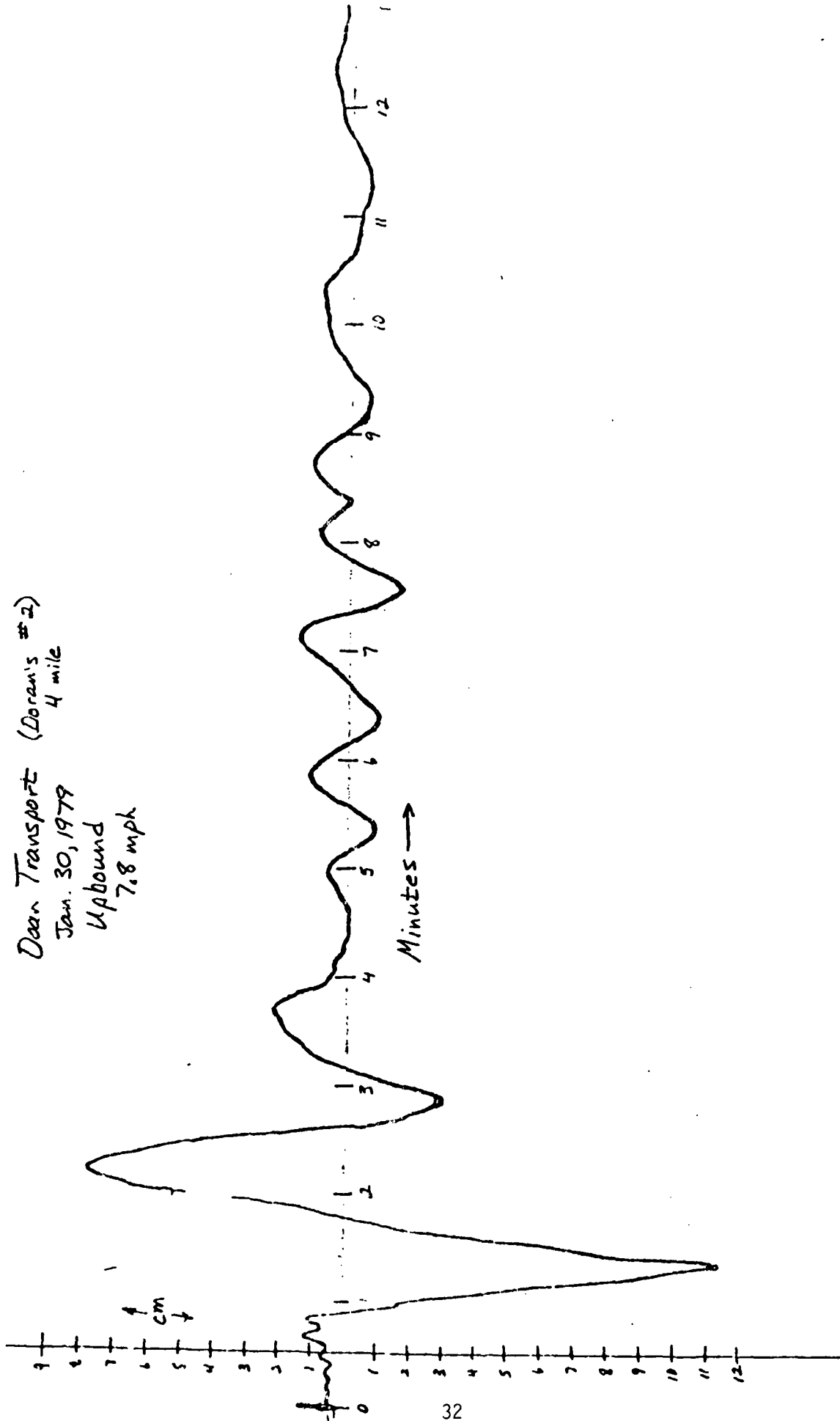
PRESQUE ISLE  
Jan. 29, 1979 Debris  
Downbound 8:38 pm  
5.4 mph



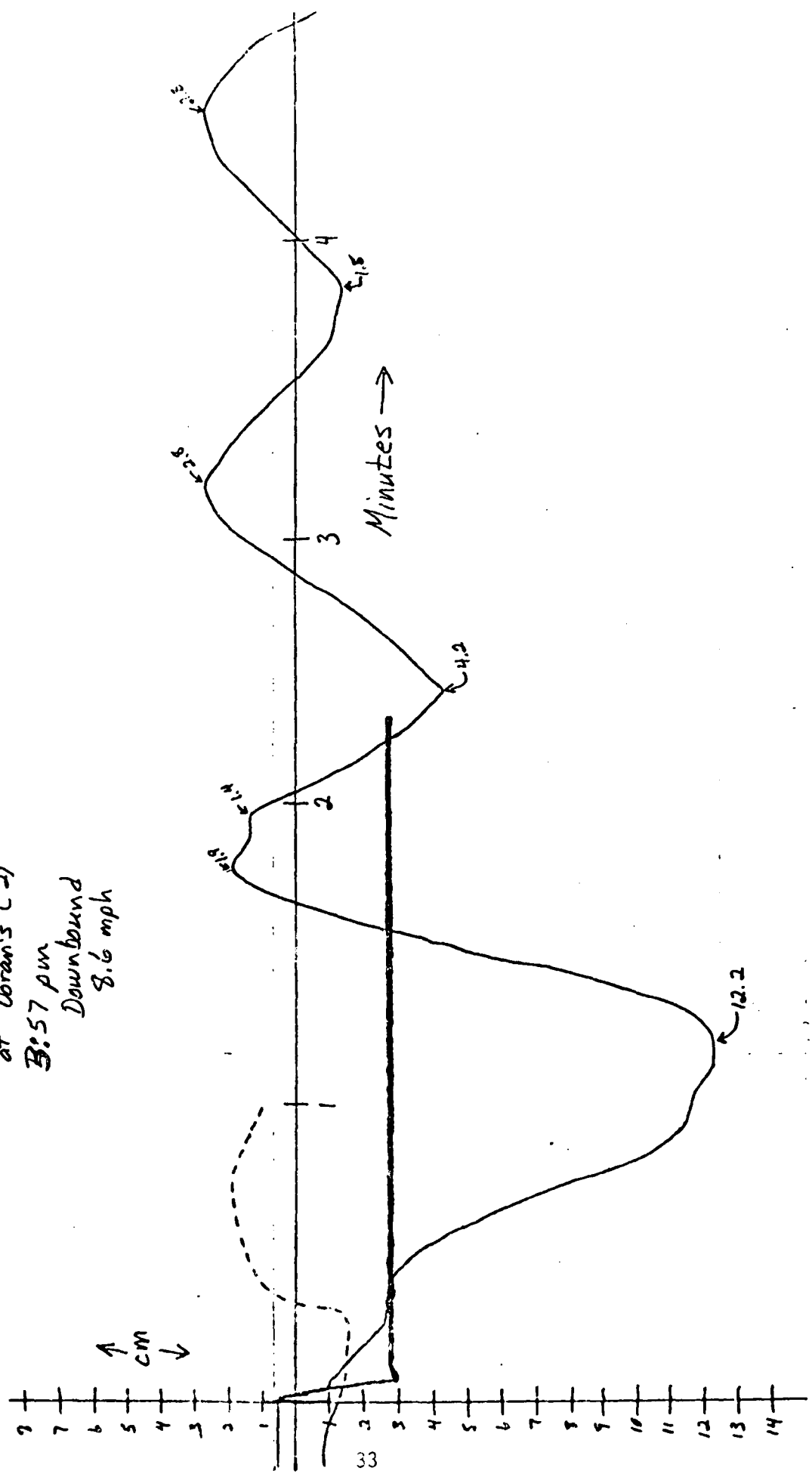
Hudson Transport  
Jan. 20, 1979  
11:11 am  
Downbound  
4.9 mph



Dear Transport (Doran's #2)  
 Jan. 30, 1979  
 Upbound  
 7.8 mph



Leon Fraser  
 Feb. 5, 1979  
 at Doran's (#2)  
 3:57 pm  
 Downbound  
 8.6 mph



C. G. Cutter Mackinac

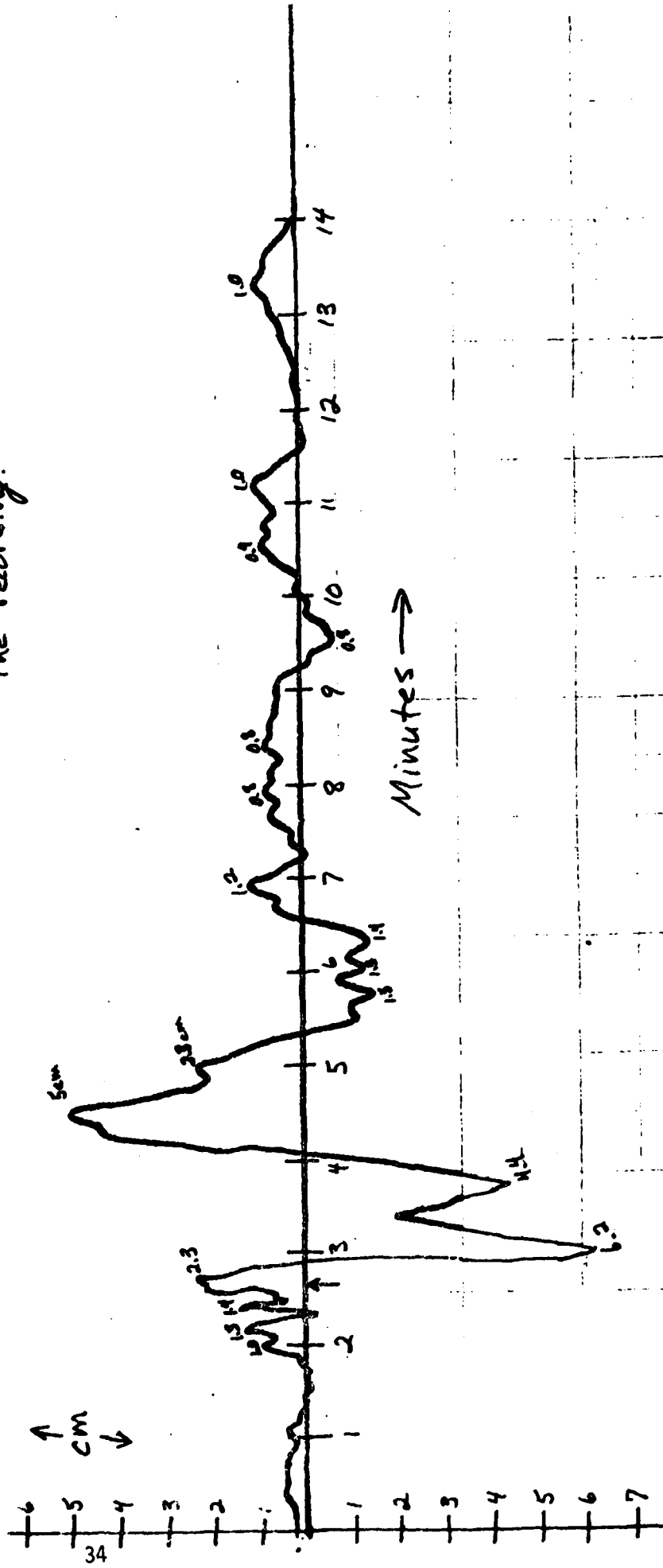
Feb. 16, 1979

10:30 am.

Doran's (4 mile road)

7.2 mph

- Mackinac was breaking channel open for 3 upbounders (i.e. Clark, Callaway, + Munson) Last ship thru was near noon on Wednesday, thus approx. 2 days of ice build-up.
- Blue arrow indicates where Mackinac began backing up - right in front of the sample location. She continued backing up for the duration of the recording.



— Obtained first crack sample on this vessel passage

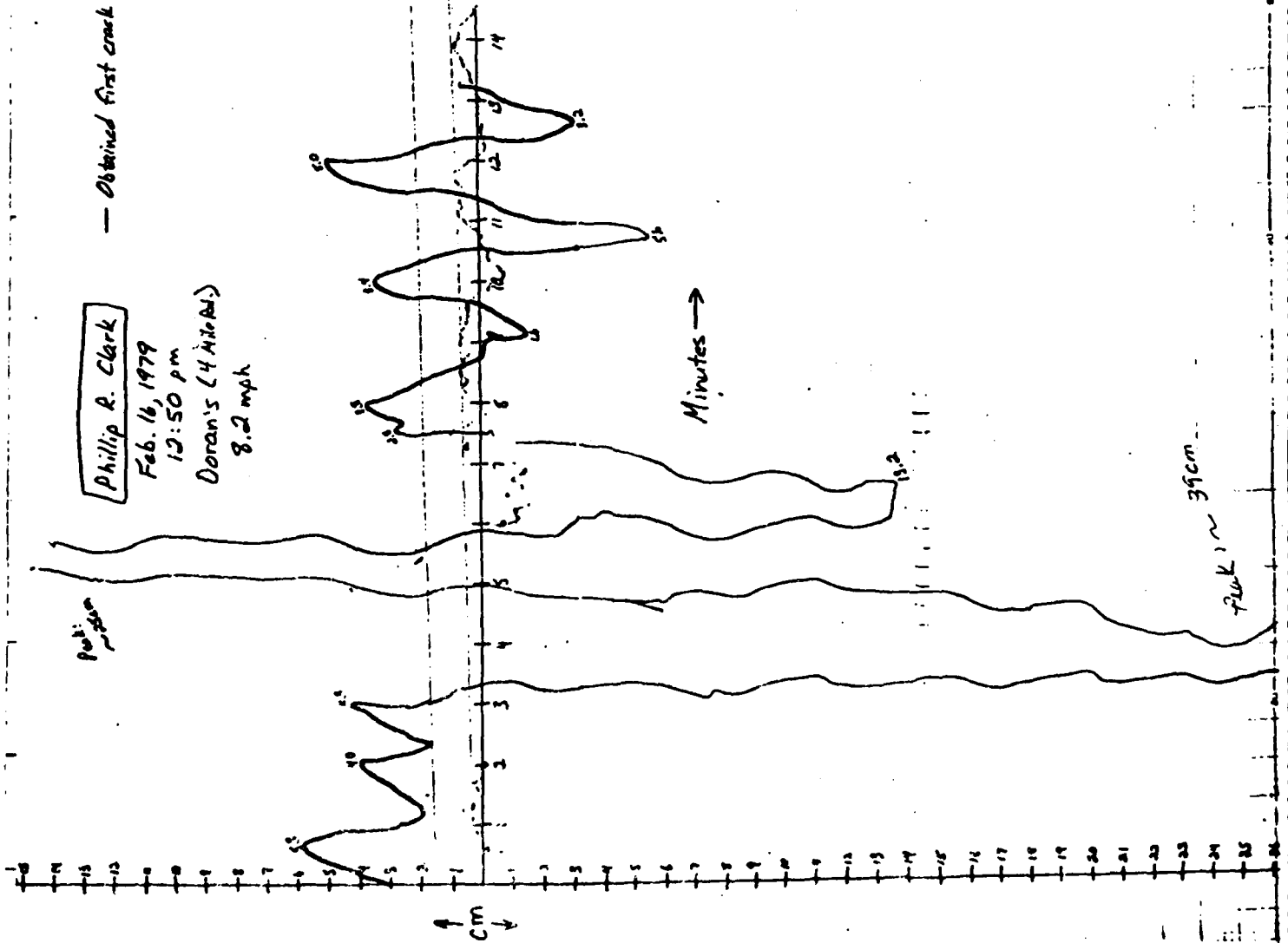
Phillip R. Clark

Feb. 16, 1979

12:50 pm

Doran's (4 MINAMI)

8.2 mph



Cason J. Callaway

Feb. 16, 1979

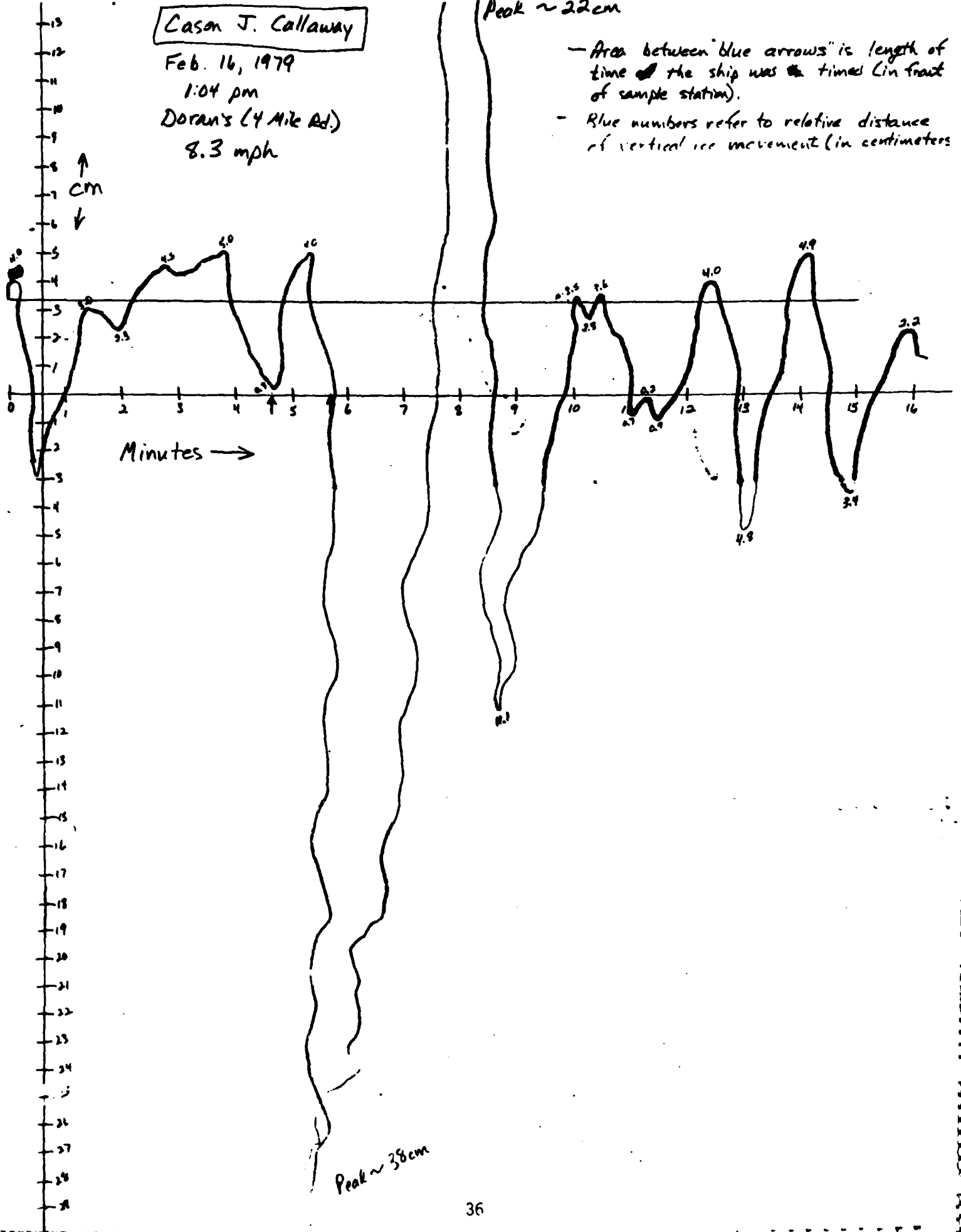
1:04 pm

Doran's (4 Mile Rd.)

8.3 mph

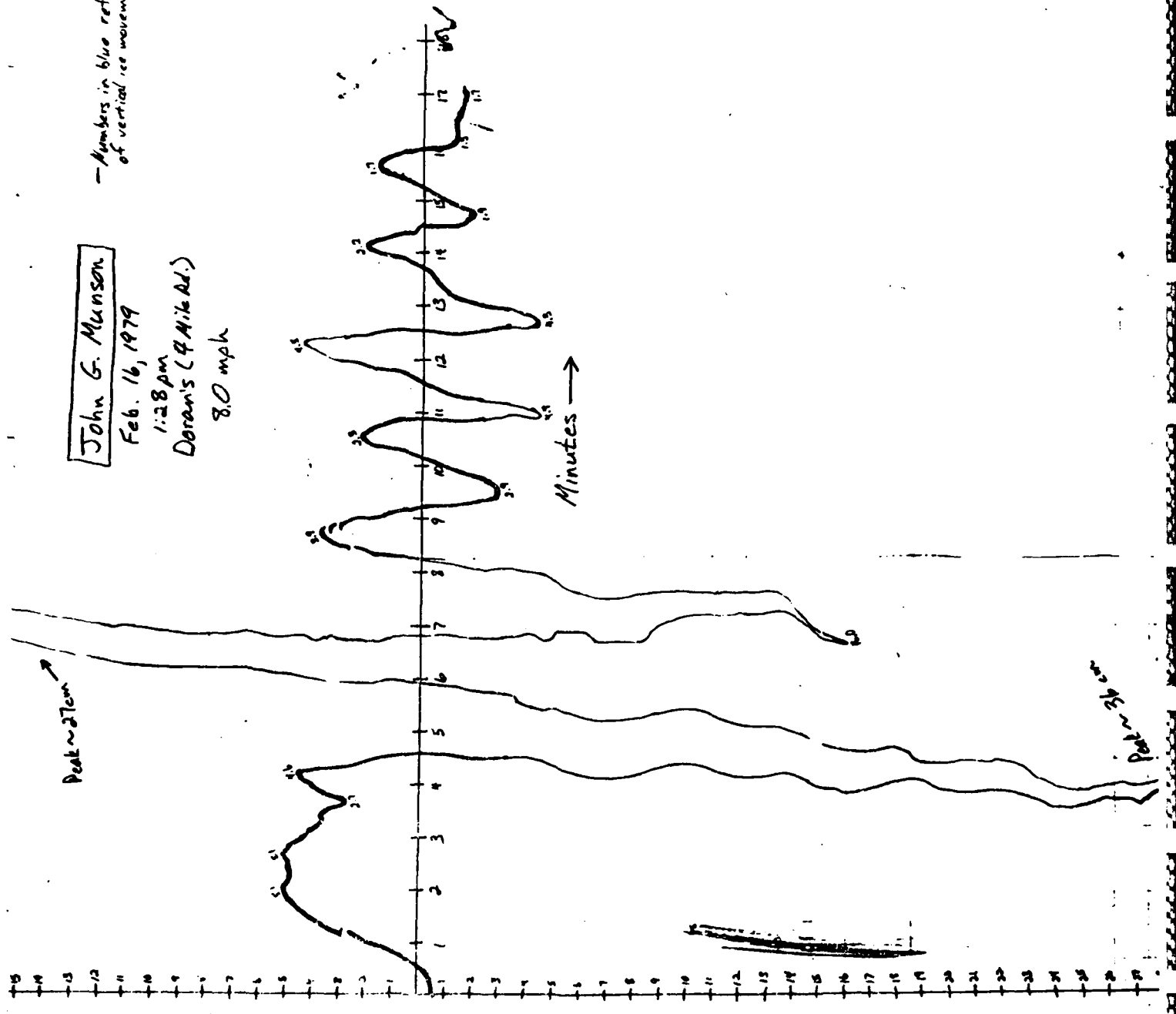
Peak ~ 22cm

- Area between blue arrows is length of time the ship was ~~the~~ timed (in fraction of sample station).
- Blue numbers refer to relative distance of vertical ice movement (in centimeters)



- Numbers in blue refer to relative distance of vertical ice movement (in centimeters).

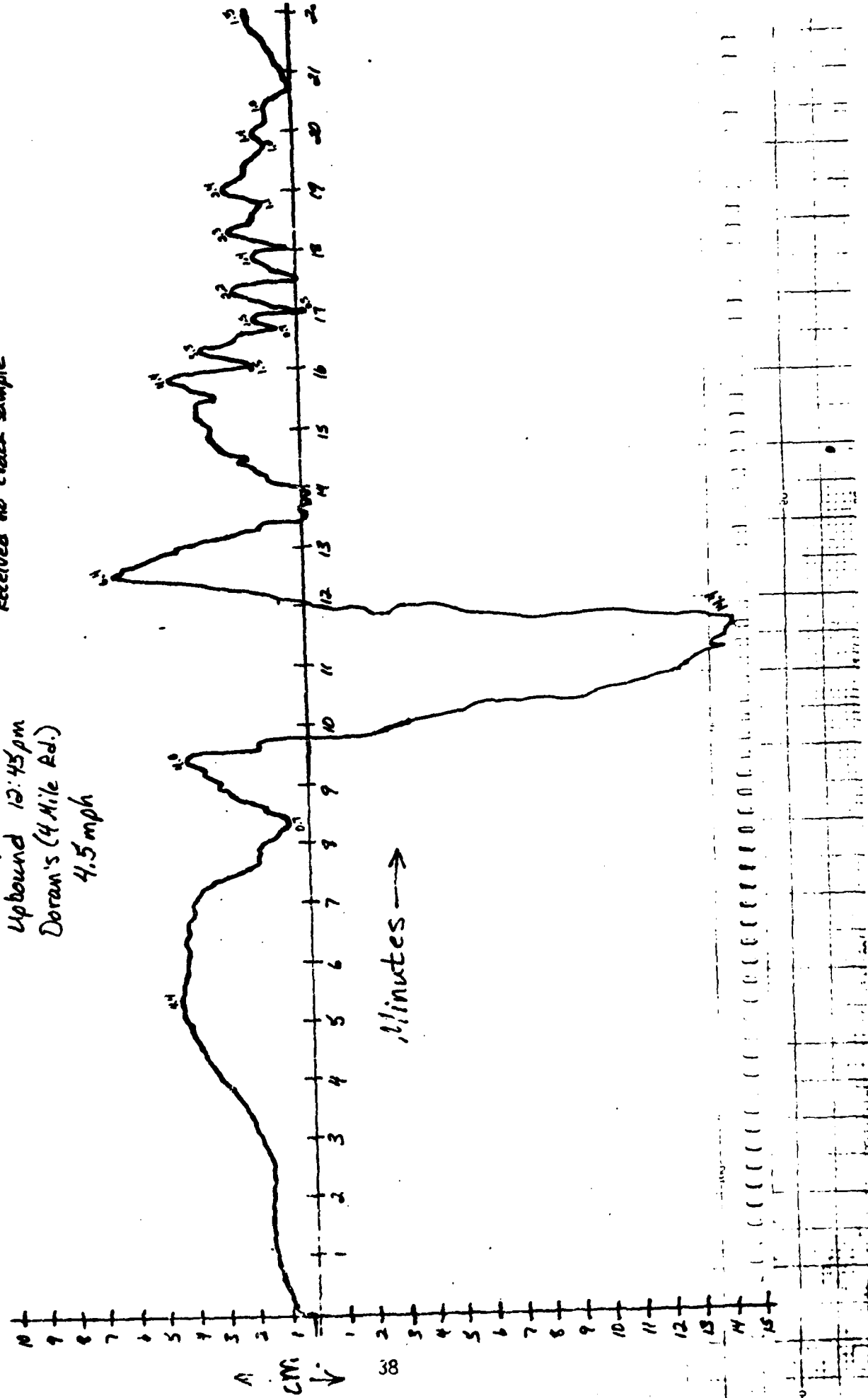
John G. Munson  
 Feb. 16, 1979  
 1:28 pm  
 Doran's (4 Mile Rd.)  
 8.0 mph



-Noticed much more ice vibration from the engine noise during this ship's passage.  
 -Received no crack sample

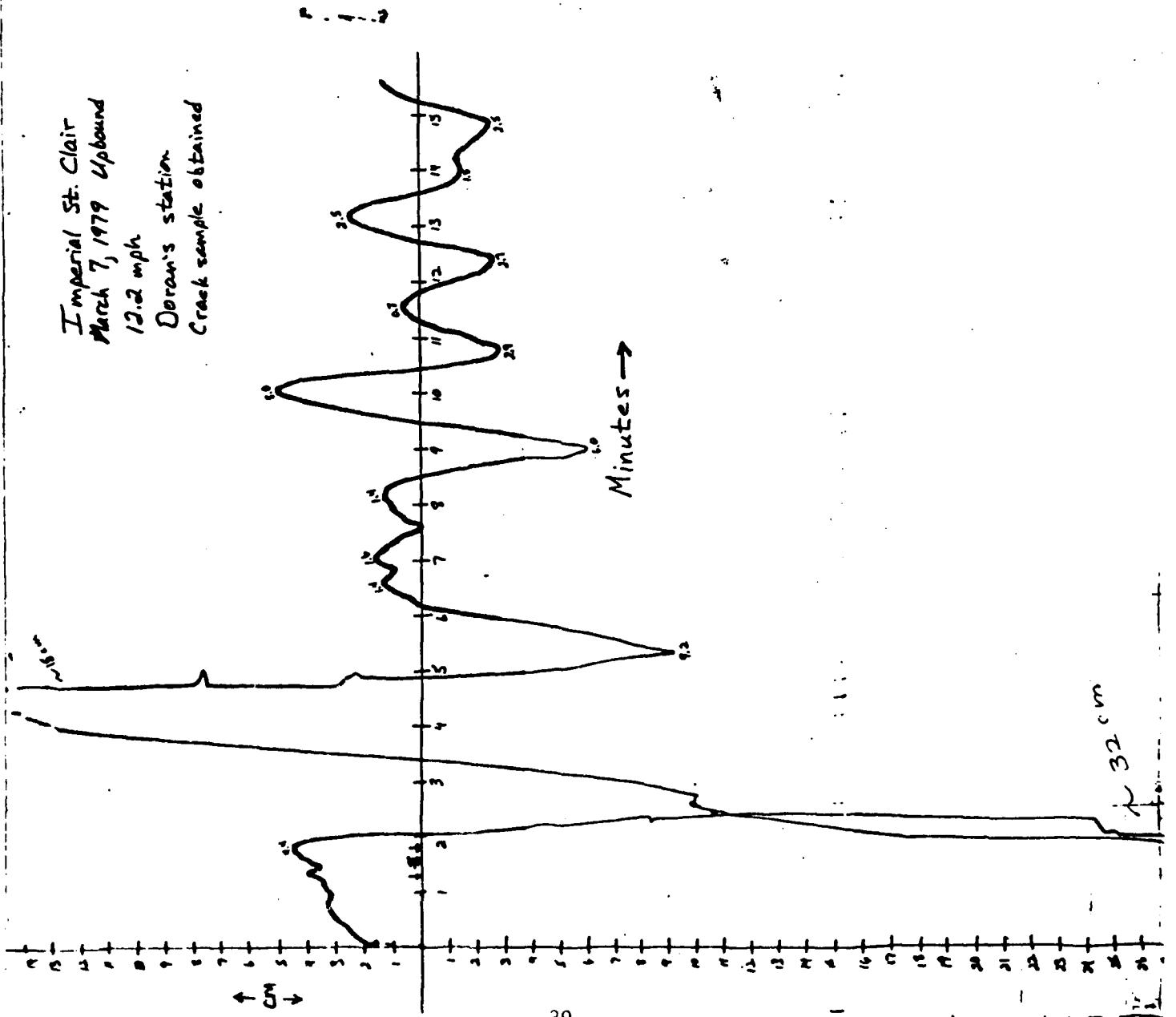
Edwin H. Gott

Feb. 19, 1979  
 Upbound 12:45 pm  
 Doran's (4 Mile Rd.)  
 4.5 mph



- 2 blue arrows indicate when vessel  
was timed directly in front of station,  
30.6 sec.

Imperial St. Clair  
March 7, 1979 Upbound  
12.2 mph  
Doran's station  
Crack sample obtained



Imperial St. Clair

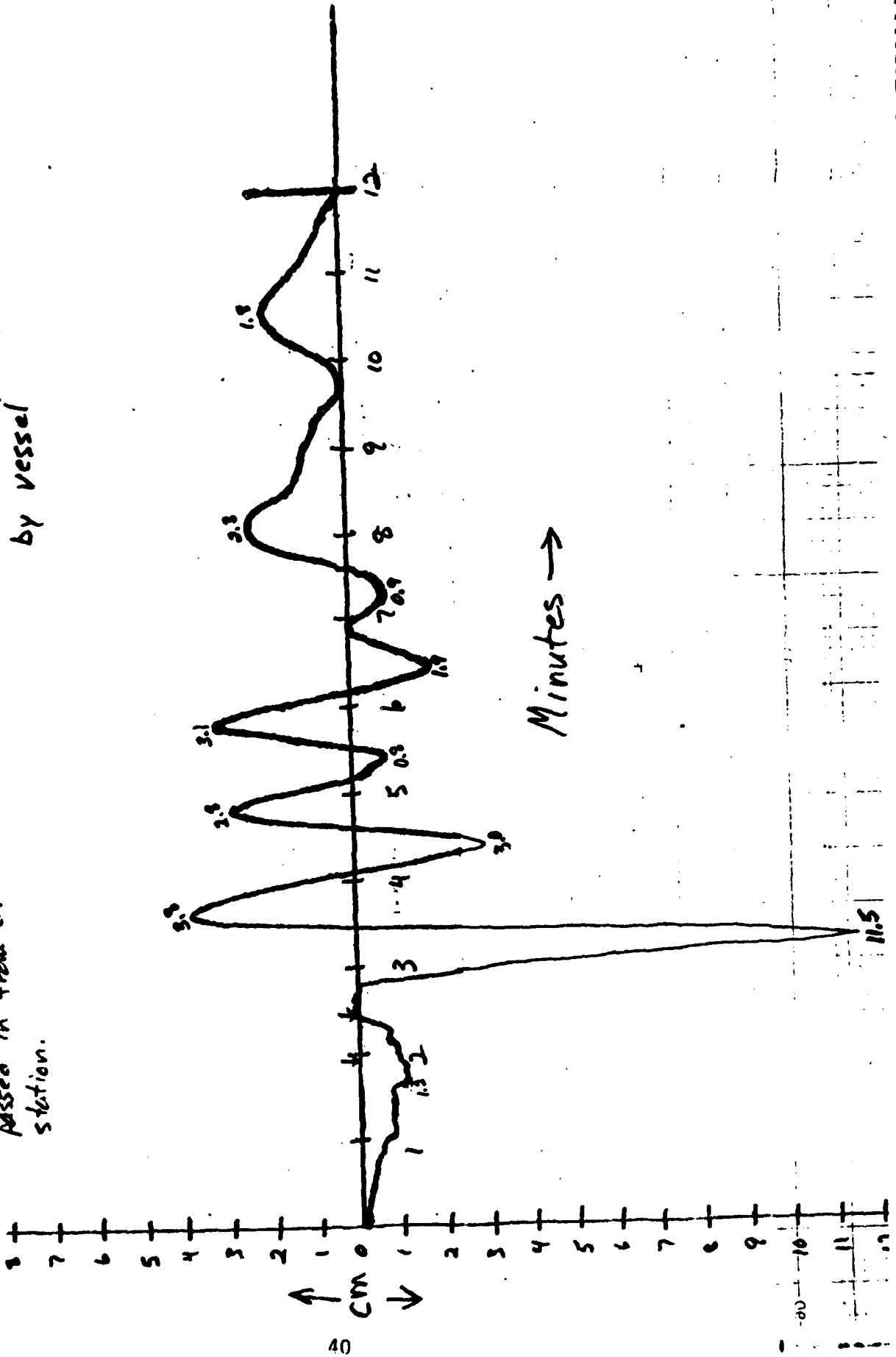
March 8, 1979 9:40am

Doran's - Downbound

9.7 mph

No crack sample produced  
by vessel

- Blue arrows indicate  
length of time ship  
passed in front of  
station.



IMPERIAL ST CLAIR

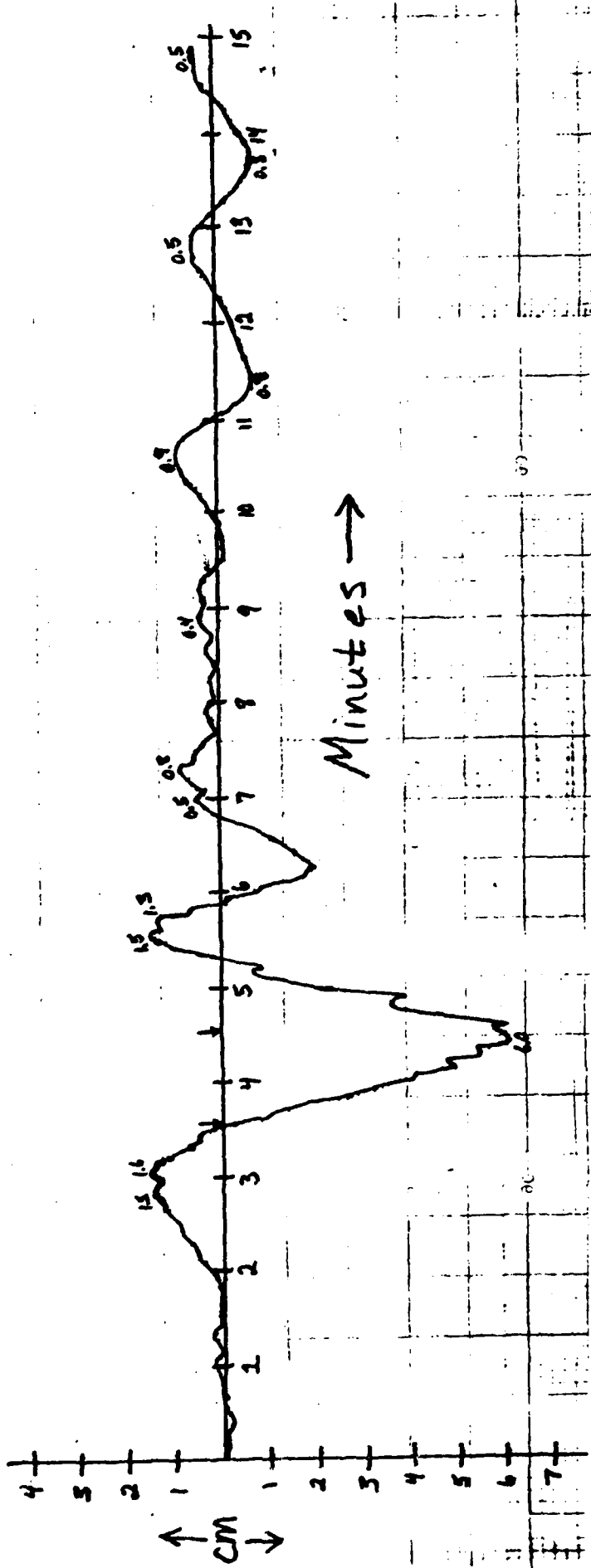
March 14, Adams - 11:02 a.m.

Upbound at 6.3 mph

Ice thickness 38 cm

Crack sample obtained - 350 ml

- Blue arrows indicate length of time  
of vessel passage in front of station.



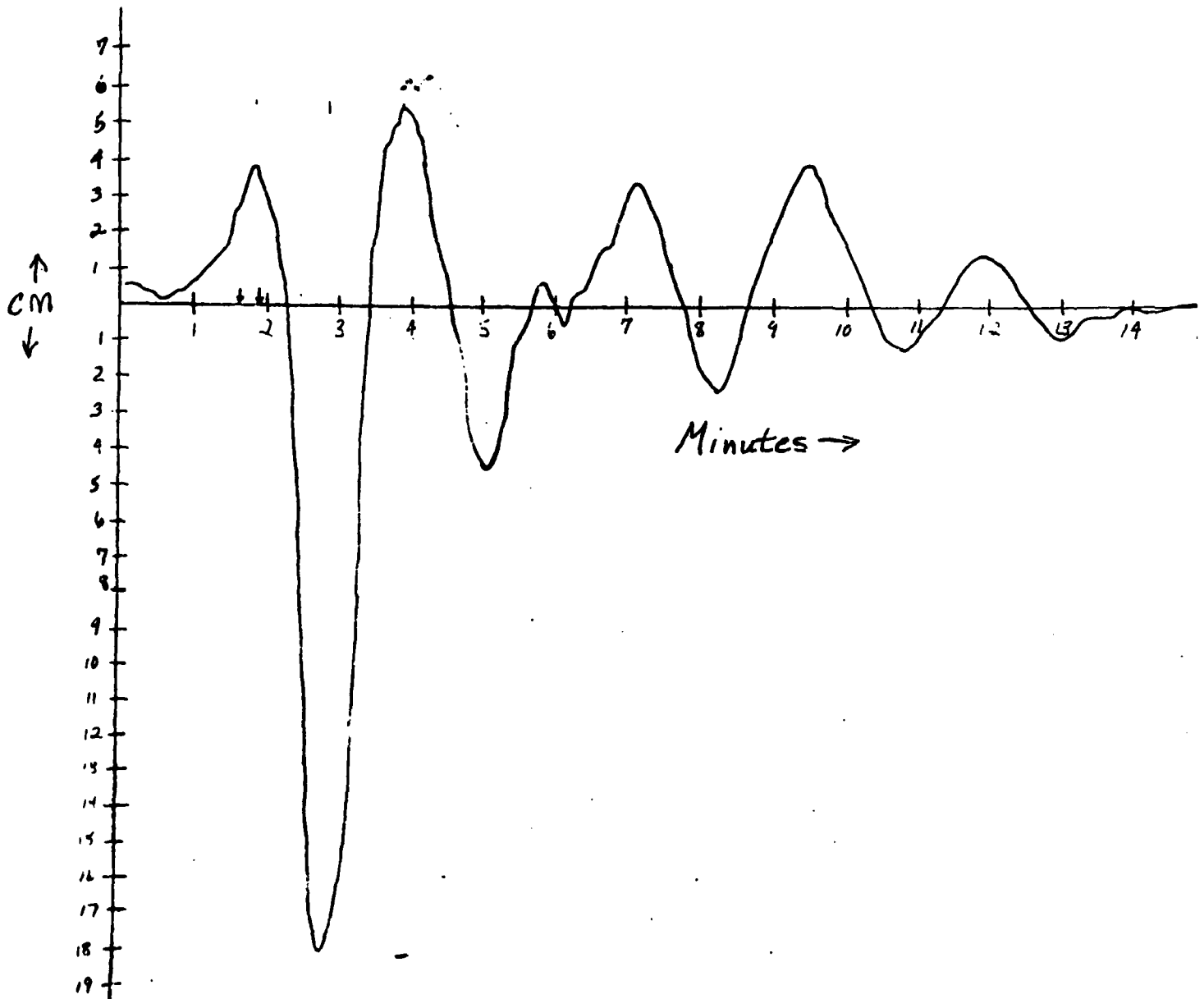
IMPERIAL ST. CLAIR

March 20, 1979 Upbound 11:30am

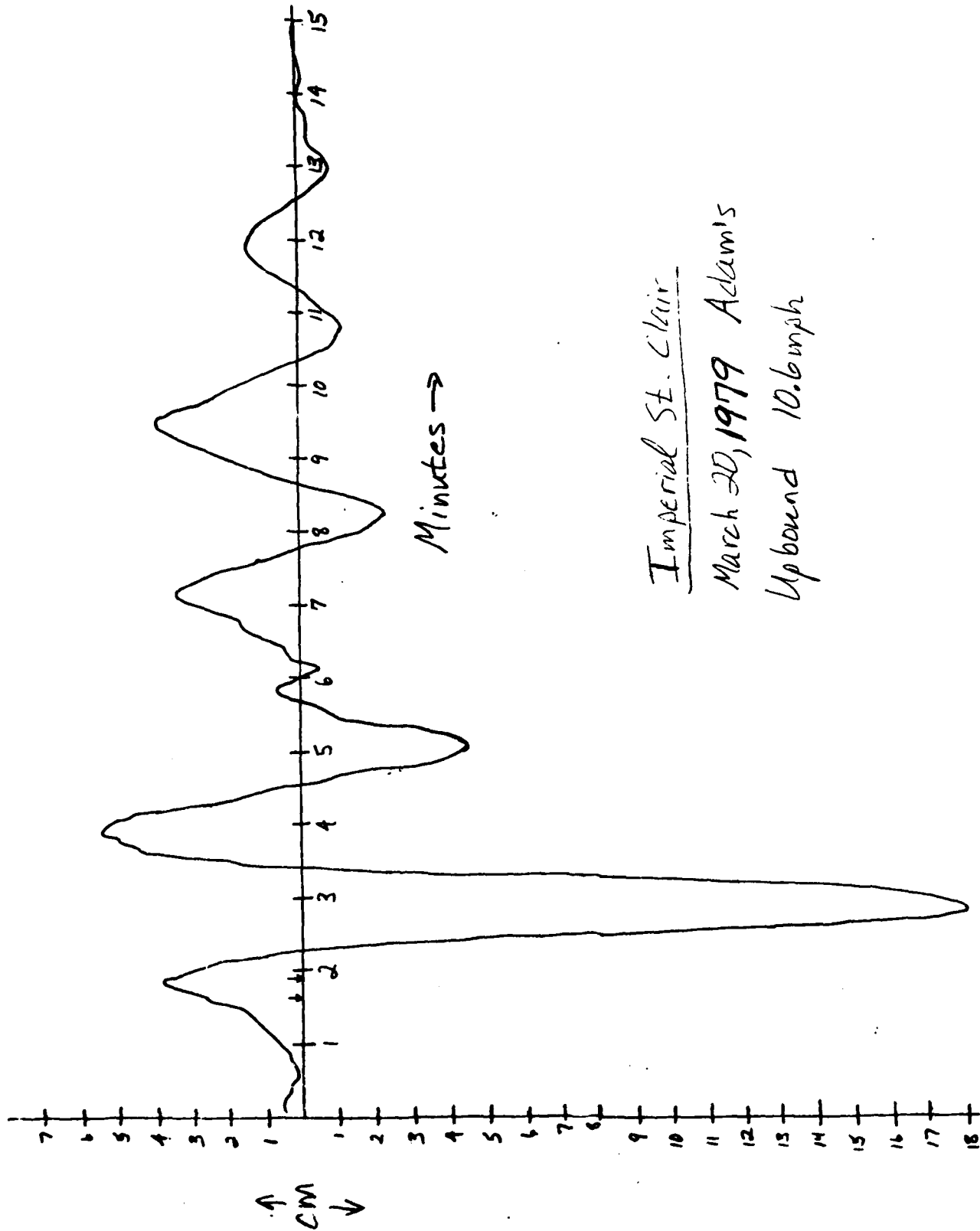
Adam's station 10.6 mph

16+8cm samplers used - no sample obtained

- Red arrows indicate time of vessel passage in front of station.



- Red arrows indicate time of vessel passage in front of station.

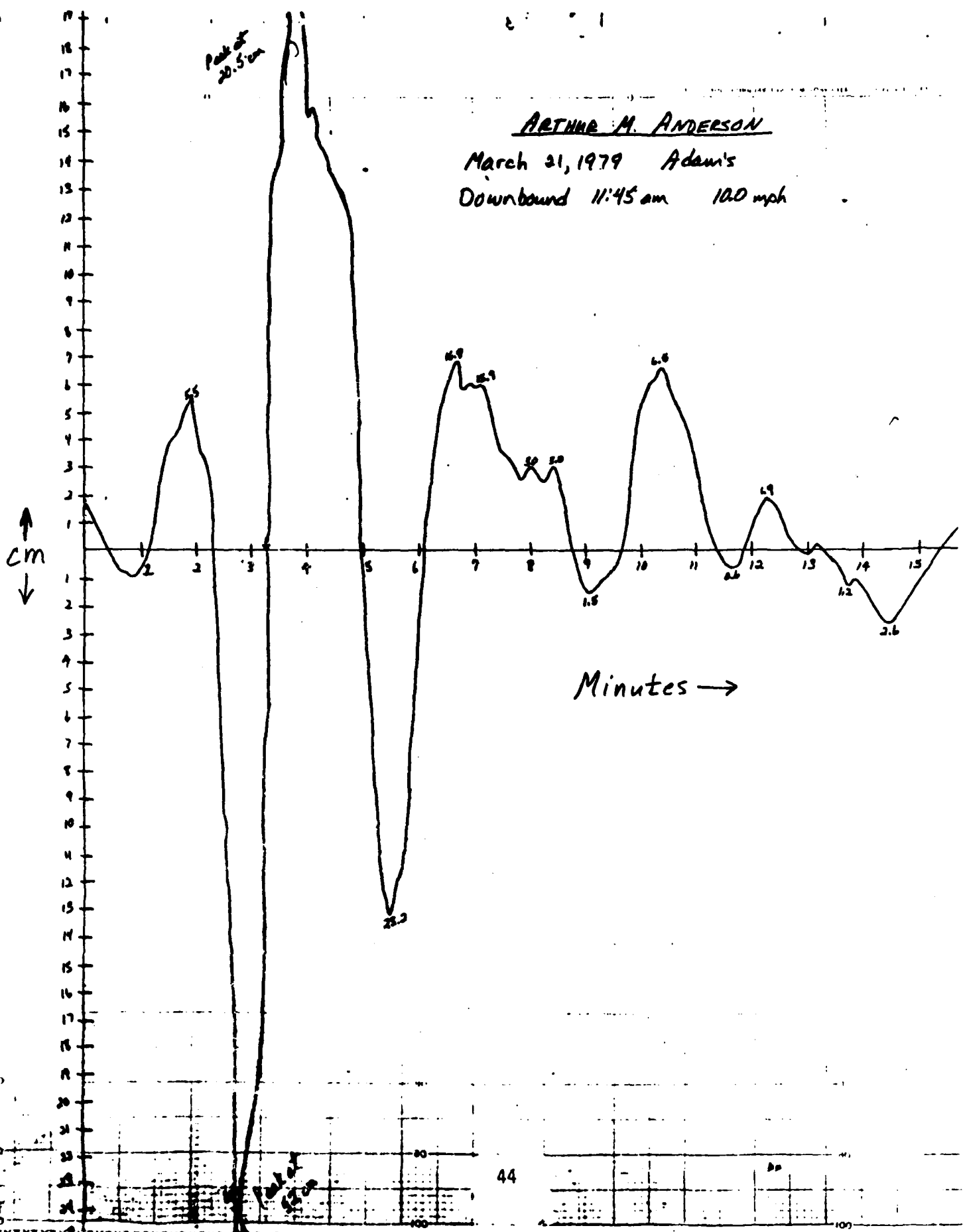


Imperial St. Clair  
March 20, 1979 Adam's  
Upbound 10.6 mph

Peak of  
20.5 cm

ARTHUR M. ANDERSON

March 31, 1979 Adam's  
Downbound 11:45 am 100 mph

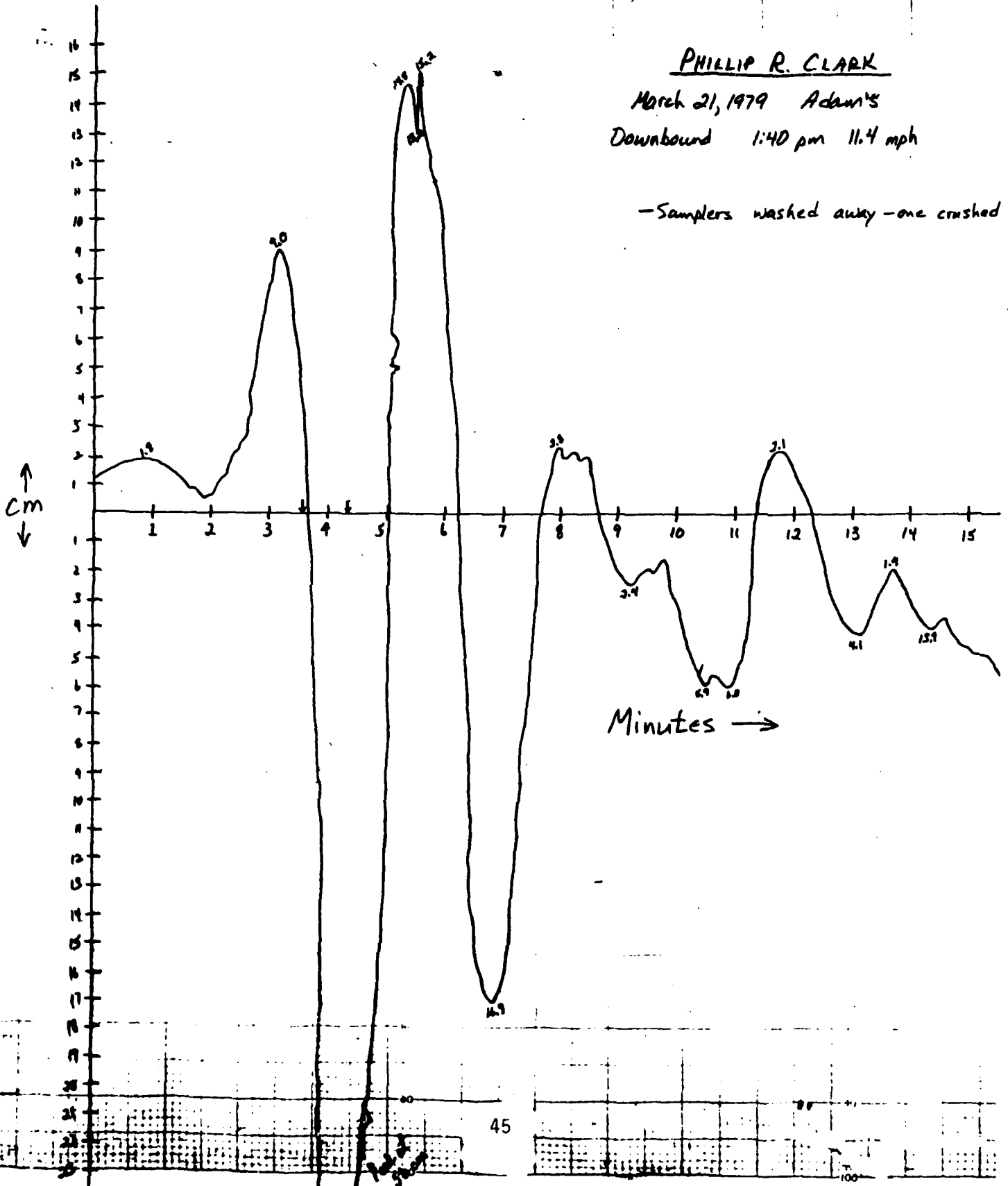


PHILLIP R. CLARK

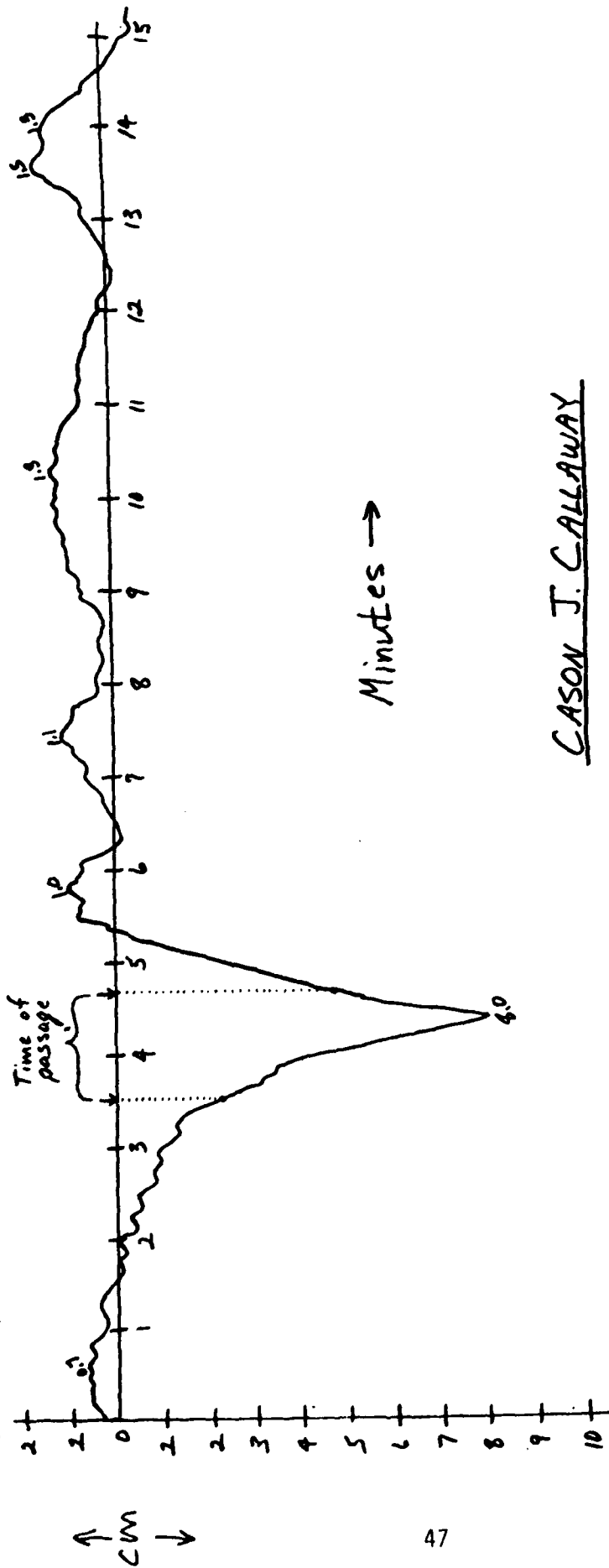
March 21, 1979 Adam's

Downbound 1:40 pm 11.4 mph

- Samplers washed away - one crushed







CASON J. CALLAWAY

March 26, 1979 Adam's 2:27pm

Downbound 7.5 mph

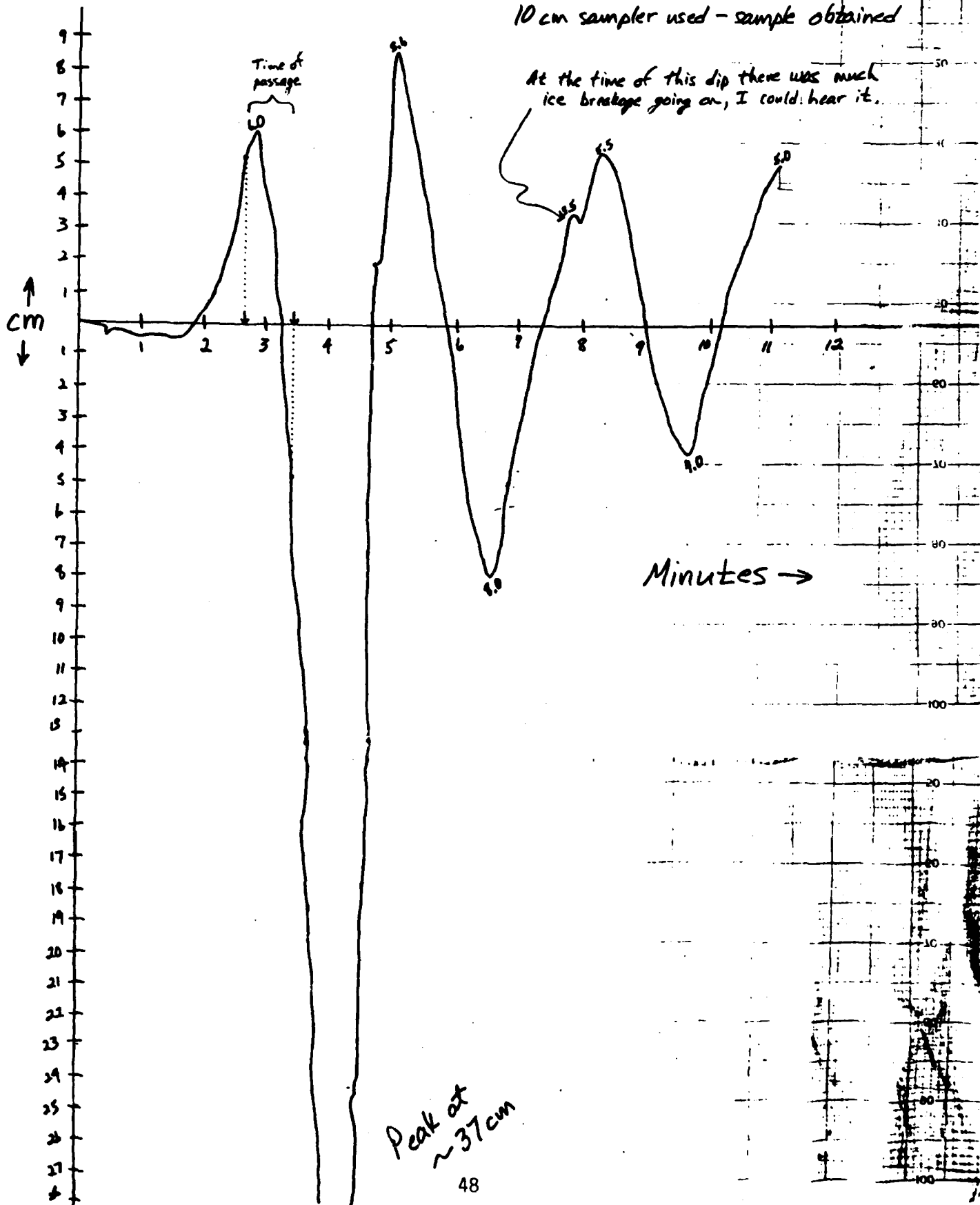
10 cm sampler used - no sample obtained

PHILLIP R. CLARK

March 27, 1979 Adam's 10:35 am

Upbound 11.5 mph

10 cm sampler used - sample obtained

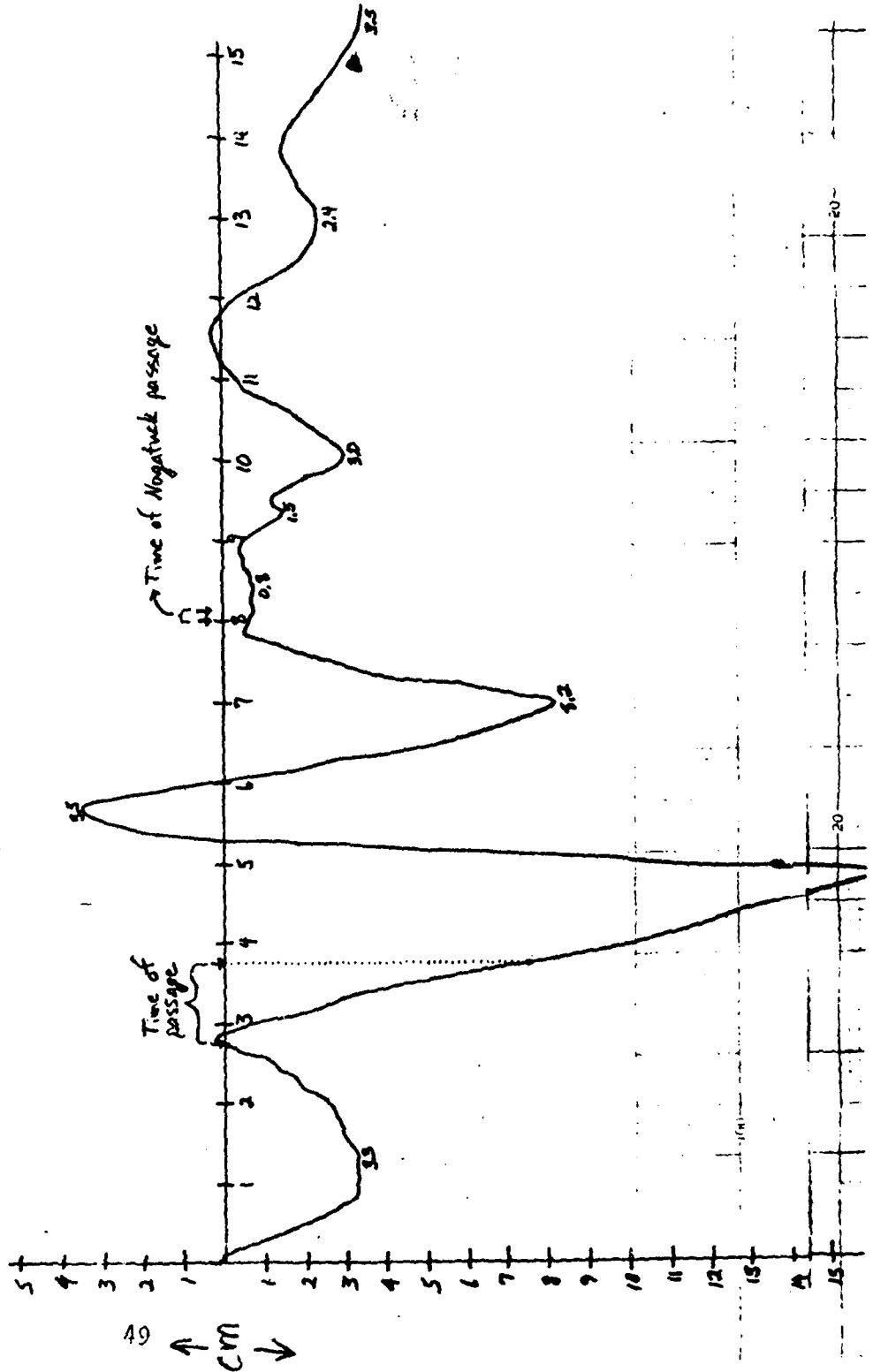


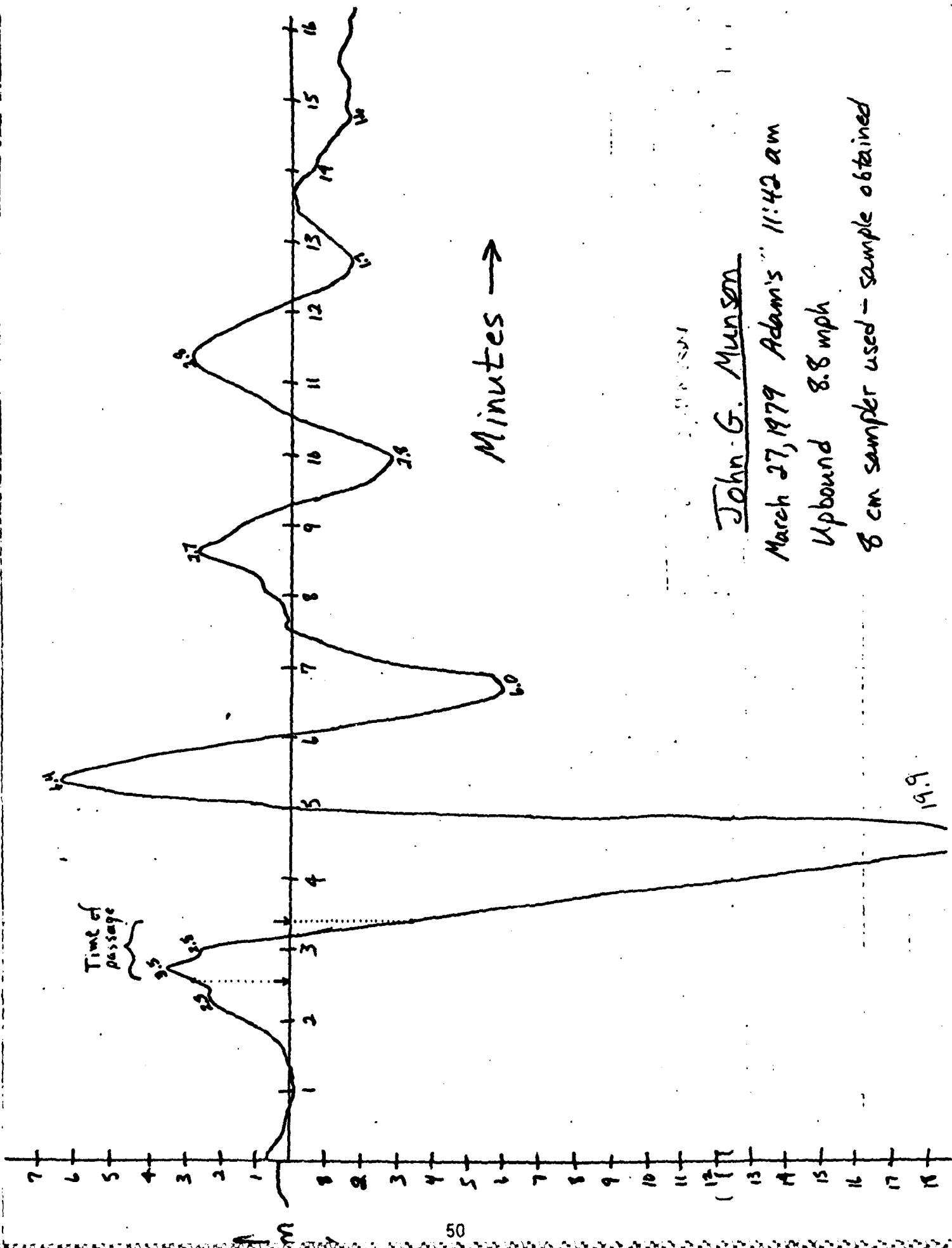
ARTHUR M. ANDERSON (+ Nogatuck)

March 27, 1979 Adams' 10:52 am

Upbound 7.2 mph

8 cm sampler used - no sample obtained





John G. Munson

March 27, 1979 Adams 11:42 am

Upbound 8.8 mph

8 cm sampler used - sample obtained

Appendix B: BENTHIC BOTTOM SAMPLE DATA

RIVERVIEW MARINA

Sample 1, January 24, 1979

<u>Description</u>	<u>Number</u>	<u>% of Sample</u>
ANNELIDA: Oligochaeta	50	18.2
ANNELIDA: Hirudinea	1	0.4
AMPHIPODA: Gammaridae-- <u>Gammarus sp.</u>	1	0.4
AMPHIPODA: Talitridae-- <u>Hyalella sp.</u>	8	2.9
HYDRACARINA	7	2.5
EPEMEROPTERA: Ephemeridae-- <u>Ephemera sp.</u>	4	1.4
EPEMEROPTERA: Ephemeridae-- <u>Hexagenea sp.</u>	3	1.1
TRICHOPTERA: Limnephilidae	3	1.1
TRICHOPTERA: Rhyacophilidae	2	0.7
TRICHOPTERA: Leptoceridae-- <u>Setodes sp.</u>	1	0.4
TRICHOPTERA: Leptoceridae-- <u>Trianodes sp.</u>	2	0.7
DIPTERA: Chironomidae--Chironominae	4	1.4
DIPTERA: Chironomidae--Orthoclaadiinae	2	0.7
DIPTERA: Chironomidae--Tanypodinae	6	2.2
DIPTERA: Heleidae	4	1.4
GASTROPODA	149	54.2
PELECYPODA	28	10.2
TOTAL: 275 organisms		

RIVERVIEW MARINA

Sample 2, January 24, 1979

<u>Description</u>	<u>Number</u>	<u>% of Sample</u>
NEMATODA	1	0.5
ANNELIDA: Oligochaeta	38	19.0
ANNELIDA: Polychaeta-- <u>Manayunkia sp.</u>	1	0.5
ISOPODA	2	1.0
HYDRACARINA	5	2.5
EPHEMEROPTERA: Ephemeridae-- <u>Ephemera sp.</u>	2	1.0
EPHEMEROPTERA: Ephemeridae-- <u>Hexagenea sp.</u>	1	0.5
TRICHOPTERA: Leptoceridae-- <u>Trianodes sp.</u>	1	0.5
DIPTERA: Chironomidae--Orthoclaadiinae	4	2.0
DIPTERA: Chironomidae--Tanypodinae	4	2.0
DIPTERA: Heleidae	2	1.0
GASTROPODA	111	55.5
PELECYPODA	28	14.0

TOTAL: 200 organisms

RIVERVIEW MARINA

Sample 3, January 24, 1979

<u>Description</u>	<u>Number</u>	<u>% of Sample</u>
ANNELIDA: Oligochaeta	81	28.3
ANNELIDA: Polychaeta-- <u>Manayunkia sp.</u>	3	1.0
AMPHIPODA: Gammaridae-- <u>Gammarus sp.</u>	2	0.7
AMPHIPODA: Talitridae-- <u>Hyaletta sp.</u>	9	3.1
HYDRACARINA	9	3.1
EPHEMEROPTERA: Caenidae	3	1.0
EPHEMEROPTERA: Ephemeridae-- <u>Ephemera sp.</u>	1	0.3
EPHEMEROPTERA: Ephemeridae-- <u>Hexagenea sp.</u>	1	0.3
TRICHOPTERA: Limnephilidae	1	0.3
TRICHOPTERA: Rhyacophilidae	4	1.4
TRICHOPTERA: Leptoceridae-- <u>Trianodes sp.</u>	2	0.7
DIPTERA: Chironomidae--Chironominae	1	0.3
DIPTERA: Chironomidae--Orthoclaadiinae	22	7.7
DIPTERA: Chironomidae--Tanypodinae	12	4.2
DIPTERA: Heleidae	3	1.0
DIPTERA: Simuliidae	1	0.3
GASTROPODA	108	37.8
PELECYPODA	24	8.4

TOTAL: 286 organisms

DORAN'S

Sample 1, January 25, 1979

<u>Description</u>	<u>Number</u>	<u>% of Sample</u>
NEMATODA	2	0.8
ANNELIDA: Oligochaeta	25	9.4
ANNELIDA: Polychaeta	2	0.8
AMPHIPODA: Gammaridae-- <u>Gammarus sp.</u>	1	0.4
AMPHIPODA: Talitridae-- <u>Hyalella sp.</u>	2	0.8
HYDRACARINA	5	1.9
TRICHOPTERA: Leptoceridae-- <u>Setodes sp.</u>	1	0.4
TRICHOPTERA: Rhyacophilidae-- <u>Wormaldia sp.</u>	1	0.4
DIPTERA: Chironomidae--Chironominae	20	7.5
DIPTERA: Chironomidae--Orthocladiinae	12	4.5
DIPTERA: Heleidae	10	3.7
GASTROPODA	161	60.3
PELECYPODA	25	9.4

TOTAL: 267 organisms

## DORAN'S

Sample 2, January 25, 1979

<u>Description</u>	<u>Number</u>	<u>% of Sample</u>
ANNELIDA: Oligochaeta	27	9.5
ISOPODA	1	0.4
AMPHIPODA: Gammaridae-- <u>Gammarus sp.</u>	2	0.7
AMPHIPODA: Talitridae-- <u>Hyalella sp.</u>	11	3.9
HYDRACARINA	7	2.5
EPHEMEROPTERA: Caenidae	1	0.4
EPHEMEROPTERA: Ephemeridae-- <u>Hexagenea sp.</u>	1	0.4
TRICHOPTERA: Leptoceridae-- <u>Setodes sp.</u>	2	0.7
TRICHOPTERA: Leptoceridae-- <u>Trianodes sp.</u>	1	0.4
DIPTERA: Chironomidae--Chironominae	21	7.4
DIPTERA: Chironomidae--Orthocladiinae	11	3.9
DIPTERA: Chironomidae--Tanypodinae	17	6.0
DIPTERA: Heleidae	8	2.8
GASTROPODA	153	54.1
PELECYPODA	21	7.1

TOTAL: 283 organisms

DORAN'S

Sample 3, January 25, 1979

<u>Description</u>	<u>Number</u>	<u>% of Sample</u>
ANNELIDA: Oligochaeta	33	11.6
ANNELIDA: Polychaeta	4	1.4
ANNELIDA: Hirudinea	2	0.7
AMPHIPODA: Talitridae-- <u>Hyaella</u> sp.	4	1.4
HYDRACARINA	3	1.0
MEGALOPTERA: Sialidae-- <u>Sialis</u> sp.	1	0.4
TRICHOPTERA: Leptoceridae-- <u>Setodes</u> sp.	1	0.4
TRICHOPTERA: Rhyacophilidae	1	0.4
DIPTERA: Chironomidae--Chironominae	16	5.6
DIPTERA: Chironomidae--Orthocladinae	17	6.0
DIPTERA: Chironomidae--Tanypodinae	12	4.2
DIPTERA: Heleidae	4	1.4
GASTROPODA	168	58.9
PELECYPODA	19	6.7

TOTAL: 285 organisms

ADAM'S

Sample 1, February 15, 1979

<u>Description</u>	<u>Number</u>	<u>% of Sample</u>
NEMATODA	1	0.4
ANNELIDA: Oligochaeta	26	10.6
ISOPODA	5	2.0
AMPHIPODA: Talitridae-- <u>Hyalella</u> sp.	2	0.8
HYDRACARINA	2	0.8
EPHEMEROPTERA: Ephemeridae-- <u>Hexagenea</u> sp.	2	0.8
TRICHOPTERA: Leptoceridae-- <u>Setodes</u> sp.	2	0.8
TRICHOPTERA: Limnephilidae	2	0.8
TRICHOPTERA: Rhyacophilidae	1	0.4
DIPTERA: Chironomidae--Chironominae	68	27.8
DIPTERA: Chironomidae--Orthocladiinae	18	7.3
DIPTERA: Heleidae	14	5.7
GASTROPODA	75	30.6
PELECYPODA	27	11.0
TOTAL: 245 organisms		

ADAM'S

Sample 2, February 15, 1979

<u>Description</u>	<u>Number</u>	<u>% of Sample</u>
ANNELIDA: Oligochaeta	25	22.3
ISOPODA	1	0.9
EPHEMEROPTERA: Ephemeridae-- <u>Hexagenea sp.</u>	2	1.8
TRICHOPTERA: Leptoceridae-- <u>Setodes sp.</u>	1	0.9
DIPTERA: Chironomidae--Chironominae	1	0.9
DIPTERA: Chironomidae--Orthocladiinae	9	8.0
DIPTERA: Chironomidae--Tanypodinae	4	3.6
DIPTERA: Heleidae	5	4.5
GASTROPODA	32	28.6
PELECYPODA	32	28.6

TOTAL: 112 organisms

ADAM'S

Sample 3, February 15, 1979

<u>Description</u>	<u>Number</u>	<u>% of Sample</u>
NEMATODA	3	5.4
ANNELIDA: Oligochaeta	13	23.6
ISOPODA	1	1.8
EPHEMEROPTERA: Ephemeridae-- <u>Ephemera</u> sp.	1	1.8
EPHEMEROPTERA: Ephemeridae-- <u>Hexagenea</u> sp.	1	1.8
TRICHOPTERA: Rhyacophilidae	1	1.8
DIPTERA: Chironomidae--Orthoclaadiinae	7	12.7
DIPTERA: Chironomidae--Tanypodinae	2	3.6
DIPTERA: Heleidae	3	5.4
GASTROPODA	14	25.4
PELECYPODA	9	16.4

TOTAL: 55 organisms

Appendix C: ALGAL DISTRIBUTION  
BY SAMPLE

Genera	Riverview			Doran's			Adam's		
	1	2	3	1	2	3	1	2	3
<u>Ulothrix sp.</u>	x	x		x	x		x		x
<u>Microspora sp.</u>								x	
<u>Rhizoclonium sp.</u>								x	
<u>Debarya sp.</u>							x		
<u>Nitella sp.</u>		x	x			x			
<u>Characiopsis sp.</u>							x		
<u>Tabellaria sp.</u>	x				x			x	x
<u>Fragilaria sp.</u>			x						x
<u>Rhoicosphenia sp.</u>		x			x		x		x
<u>Stauroneis sp.</u>							x		
<u>Gomphoneis sp.</u>			x	x			x		
<u>Cymbella sp.</u>	x	x	x	x		x		x	x
<u>Campylodiscus sp.</u>								x	
<u>Oscilliatora sp.</u>								x	

Appendix D

PERCENT COMPOSITION OF CRACK SAMPLES

Date	Location	Vessel Description	(cm) Sampler Size	% Water	% Benthos	% Other
<u>400-700 Ft. (118.5-207.4 m)</u>						
<u>5-10 mph (8-16 kph)</u>						
3/27/79	Adam's	Arthur M. Anderson	8	0.00	0.00	0.00
3/27/79	Adam's	John G. Munson	8	99.86	0.00	.14
3/07/79	Doran's	Imperial St. Clair	16	99.90	0.00	.10
3/07/79	Doran's	Imperial St. Clair	8	99.94	0.00	.06
3/08/79	Doran's	Imperial St. Clair	8	0.00	0.00	0.00
3/08/79	Doran's	Imperial St. Clair	16	0.00	0.00	0.00
3/14/79	Adam's	Imperial St. Clair	16	99.83	0.00	.17
3/21/79	Adam's	Arthur M. Anderson	8	0.00	0.00	0.00
3/21/79	Adam's	Arthur M. Anderson	16	0.00	0.00	0.00
<u>Over 10 mph (16 kph)</u>						
3/20/79	Adam's	Imperial St. Clair	8	0.00	0.00	0.00
3/20/79	Adam's	Imperial St. Clair	16	0.00	0.00	0.00
<u>700-1000 Ft. (207.4-296.3 m)</u>						
<u>5-10 mph (8-16 kph)</u>						
2/16/79	Doran's	Phillip R. Clark	16*	99.98	.02	0.00
3/18/79	Adam's	Roger Blough	8	99.83	.03	.14
3/18/79	Doran's	Roger Blough	10	99.82	.07	.11
3/18/79	Adam's	Roger Blough	16	99.99	0.00	.01
3/26/79	Adam's	Cason J. Callaway	10	0.00	0.00	0.00
3/26/79	Adam's	Roger Blough	10	0.00	0.00	0.00
<u>Over 10 mph (16 kph)</u>						
3/21/79	Adam's	Phillip R. Clark	8	99.37	.30	.33
3/21/79	Adam's	Phillip R. Clark	16	99.89	.07	.04
3/27/79	Adam's	Phillip R. Clark	10	99.87	0.00	.13

\* Was first attempted sampler and was found to be ineffective for large volumes. Replaced later with described sampling apparatus.

Appendix E: KYMOGRAPH RECORDINGS LOG

<u>Date</u>	<u>Location</u>	<u>Vessel Name</u>	<u>(mph) Speed</u>	<u>Direction</u>
1-26	Riverview	Enders M. Voorhees	8.9	Upbound
1-26	Riverview	Katamai Bay	11.2	Upbound
1-29	Doran's	C. G. Cutter Mackinaw	7.0	Upbound
1-29	Doran's	Cason J. Callaway	11.0	Downbound
1-29	Doran's	Presque Isle	5.3	Downbound
1-30	Doran's	Hudson Transport	4.9	Downbound
1-30	Doran's	Doan Transport	7.8	Upbound
2-5	Doran's	Leon Fraser	8.6	Downbound
2-16	Doran's	C. G. Cutter Mackinaw	7.2	Upbound
2-16	Doran's	Phillip R. Clark	8.2	Upbound
2-16	Doran's	Cason J. Callaway	8.3	Upbound
2-16	Doran's	John G. Munson	8.0	Upbound
2-19	Doran's	Edwin H. Gott	4.5	Upbound
3-7	Doran's	Imperial St. Clair	9.7	Upbound
3-8	Doran's	Imperial St. Clair	9.7	Downbound
3-14	Adam's	Imperial St. Clair	6.3	Upbound
3-20	Adam's	Imperial St. Clair	10.6	Upbound
3-21	Adam's	Arthur M. Anderson	10.0	Downbound
3-21	Adam's	Phillip R. Clark	11.4	Downbound
3-26	Adam's	Roger Blough	7.3	Downbound
3-26	Adam's	Cason J. Callaway	7.5	Downbound
3-27	Adam's	Phillip R. Clark	11.5	Upbound
3-27	Adam's	Arthur M. Anderson	7.2	Upbound
3-27	Adam's	John G. Munson	8.8	Upbound

APPENDIX F  
VESSEL BEAM, DRAFT & RELATIVE VELOCITY  
vs.  
VOLUME DISPLACED

DATE	VESSEL	DIRECTION	(mph) RELATIVE VELOCITY*	(ft.) BEAM	(ft.) DRAFT	(ml) VOLUME DISPLACED	(cm) SAMPLER SIZE**
2-16	Phillip R. Clark	Upbound	8.9	70	22	12,000	16
3-7	Imperial St. Clair	Upbound	10.4	74	20	15,300	8
3-7	Imperial St. Clair	Upbound	10.4	74	20	7,400	8
3-14	Imperial St. Clair	Upbound	7.0	74	24	350	16
3-18	Roger Blough	Upbound	16.0	105	24	5,790	10
3-18	Roger Blough	Upbound	16.0	105	24	1,625	16
3-18	Roger Blough	Upbound	16.0	105	24	6,300	8
3-21	Phillip R. Clark	Downbound	10.7	70	25.5	400	16
3-21	Phillip R. Clark	Downbound	10.7	70	25.5	2,000	8
3-27	John G. Munson	Upbound	9.5	72	20	70	8
3-27	Phillip R. Clark	Upbound	12.2	70	21.5	75	10

\*Relative Velocity = shore speed + current factor of .72 mph.

\*\*Sampler size refers to the 3 mouth width sizes of the samplers used (i.e. 8, 10 and 16 cm wide). For clearer description see Methodology section of text, page 3.

Appendix G: CRACK SAMPLE LOG AND PERCENT TRANSMITTANCE

<u>DATE</u>	<u>LOCATION</u>	<u>VESSEL</u>	<u>DIRECTION</u>	<u>(cm) SAMPLER SIZE</u>	<u>(ml) VOLUME DISPLACED</u>	<u>(JTU) PERCENT TRANSMITTANCE</u>
2-16	Doran's	Phillip R. Clark	Upbound	16	12,000	—
3-7	Doran's	Imperial St. Clair	Upbound	16	15,300	92
3-7	Doran's	Imperial St. Clair	Upbound	8	7,400	94
3-8	Doran's	Imperial St. Clair	Downbound	16	-0-	—
3-8	Doran's	Imperial St. Clair	Downbound	8	-0-	—
3-14	Adam's	Imperial St. Clair	Upbound	16	350	95
3-18	Doran's	Roger Blough	Upbound	10	5,790	89
3-18	Adam's	Roger Blough	Upbound	16	1,625	96
3-18	Adam's	Roger Blough	Upbound	8	6,300	96.5
3-20	Adam's	Imperial St. Clair	Upbound	16	-0-	—
3-20	Adam's	Imperial St. Clair	Upbound	8	-0-	—
3-21	Adam's	Arthur M. Anderson	Downbound	16	-0-	—
3-21	Adam's	Arthur M. Anderson	Downbound	8	-0-	—
3-21	Adam's	Phillip R. Clark	Downbound	16	400	88
3-21	Adam's	Phillip R. Clark	Downbound	8	2,000	81
3-26	Adam's	Roger R. Blough	Downbound	10	-0-	—
3-26	Adam's	Cason J. Callaway	Downbound	10	-0-	—
3-27	Adam's	Phillip R. Clark	Upbound	10	75	79
3-27	Adam's	Arthur M. Anderson	Upbound	8	-0-	—
3-27	Adam's	John G. Munson	Upbound	8	70	73

END

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