MISCELLANEOUS PAPER H-69-2

RADIOACTIVE SEDIMENT TRACER TESTS HOUSTON SHIP CHANNEL, HOUSTON, TEXAS

by

E. D. Hart

March 1969

Sponsored by

U. S. Army Engineer District
Galveston

Conducted by

U. S. Army Engineer Waterways Experiment Station
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ARMY-MRC VICKSBURG, MISS.

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Foreword

The prototype tests described in this paper were conducted during August and September of 1967, with supporting tests of lesser magnitude being conducted in June and August of 1968. The tests were conducted by the U. S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the U. S. Army Engineer District, Galveston.

Acknowledgment is made to the many individuals of the Galveston District who actively participated in this investigation. Mr. E. D. Hart, Chief, Prototype Section, was test coordinator for the WES. This paper was prepared by Mr. Hart under the general supervision of Mr. E. B. Pickett, Chief, Hydraulic Analysis Branch, and Mr. E. P. Fortson, Jr., Chief, Hydraulics Division, WES.

COL John R. Oswalt, Jr., CE, and COL Levi A. Brown, CE, were successive Directors of WES during the investigation and the preparation and publication of this paper. Mr. J. B. Tiffany was Technical Director.

Contents

Conversion Factors, British to Metric Units of Measurement

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles	1.609344	kilometers
square feet	0.092903	square meters
cubic feet	0.0283168	cubic meters
feet per second	0.3048	meters per second
miles per hour	1.609344	kilometers per hour
cubic feet per second	0.0283168	cubic meters per second
Fahrenheit degrees	5/9	Celsius or Kelvin degrees*

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

Summary

Radioactive sediment tracer tests were conducted in the Houston Ship Channel to determine qualitatively the sediment movement in the channel. About 5 curies of the isotope $gold^{198}$ was thoroughly mixed with sediment samples from the channel, and the activated sediment was then deposited along the bottom at two locations.

The results of tracing the deposits indicated that the activated sediment moved upstream for several miles. Activity was recorded downstream for only a short distance. Very little lateral movement out of the channel was detected.

RADIOACTIVE SEDIMENT TRACER TESTS
HOUSTON SHIP CHANNEL, HOUSTON, TEXAS

Background

1. The 52-mile-long* Houston Ship Channel extends from the Gulf of Mexico to Houston, Texas. The course of the channel, beginning at Bolivar Peninsula, is shown in plate 1. The authorized project channel for the first 40 miles is 40 ft deep and 400 ft wide. Dimensions for the remaining distance are smaller.

2. The cost of maintenance dredging in the channel has averaged more than $1,000,000 per year over a period of several years. This high cost is primarily due to heavy shoaling and the lack of sufficient spoil areas near the channel reaches that shoal rapidly.

3. A hydraulic model of the channel has been constructed at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. An objective of the model is to determine if modifications of shoaling patterns can be induced to either reduce the shoaling or transfer it to areas where it can be removed at a lesser cost.

The Problem

4. Preliminary model shoaling verification tests indicated that once the sediment settled to the bottom it tended to remain in place. Movement under the influence of tidal currents was not detected. It was concluded that sediment movement should be monitored in the prototype. The purpose was to either confirm the above indications from the model or, if significant movement of sediment was noted in the prototype, to provide a basis for adjustment of the model to make it react in a similar manner.

5. Radioactive tracer tests were approved as the means of monitoring

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* A table of factors for converting British units of measurement to metric units is presented on page ix.

the prototype sediment movement. Locations of the two test sites investigated during the study are shown in plate 1.

Previous Radioactive Tracer Studies

6. The most noteworthy sedimentation tracer research conducted in the United States has been the work done in San Francisco Bay by the University of California, Berkeley, for the U. S. Army Engineer District, San Francisco. Since 1956, both laboratory and field experiments involving sediment transport have been conducted under the direction of Dr. R. B. Krone of the University of California. As a result of this work, methods for tracing sediment processes, including tracer preparation, labeling, and detection, have evolved. This work has been well documented.[1-6]

7. The Corps of Engineers has taken advantage of this research to establish at the WES the capability for performing sediment tracing experiments. With guidance from the University of California, and through attendance at special courses at the Oak Ridge Institute of Nuclear Studies, WES personnel have been trained in the use and handling of radioisotopes. Special instrumentation and handling equipment have been procured, thus enabling the WES to provide service in this field to all Corps of Engineers installations. Previous investigations have been made in the Galveston Harbor Entrance, Texas,[7] and in Cape Fear River, North Carolina.[8]

Scope of this Study

8. Tests were conducted to indicate the movement of sediment in the Houston Ship Channel without regard to quantity. Surveys were conducted on the shoulders of the channel to determine if any of the sediment moved outside the channel. Hydrologic and meteorologic data were collected during the period of the tests. Due to the nature of the isotope utilized, one week was allotted for each of the two tests.

Test Equipment and Material

Isotope

9. The isotope selected for use as the sediment label was $gold^{198}$. It was chosen primarily because of:

- a. Previous experience with the isotope.
- b. The favorable sorption properties[2] of the local sediment for gold.
- c. The short half-life of the isotope (2.7 days).
- d. The essentially monoenergetic property of the isotope (0.41 Mev, considered a low energy).
- e. The fact that this isotope is not known to be essential to the metabolic process of aquatic biota[2] of the area.

10. The isotope, in the form of auric chloride, was obtained from a local distributor in the Houston area. Delivery was made on the date of each release, so that no storage facility was necessary. The activity of each delivery was read at the time of receipt. Activities of the first and second isotope deliveries were approximately 4.4 and 2.6 curies, respectively.

Survey boat

11. A 40-ft, aluminum hull boat and boat operators were provided for the tests by the U. S. Army Engineer District, Galveston. WES personnel equipped the boat with the necessary apparatus and equipment to perform both the release and survey operations.

Mixing and release tank

12. In order to minimize radiation hazards, the mixing and release of the isotope and sample sediment was done remotely. To accomplish this, a cylindrical tank was constructed as shown in fig. 1. It was equipped with a mixing device, a receptacle for introducing the isotope (crusher tube), and an ejection and back-flushing system. The floating platform on which the tank rode is also shown in fig. 1.

Instrumentation

13. A sled-mounted scintillation detector (fig. 2) was towed along the bottom behind the boat at a distance of about 200 ft. The detector,

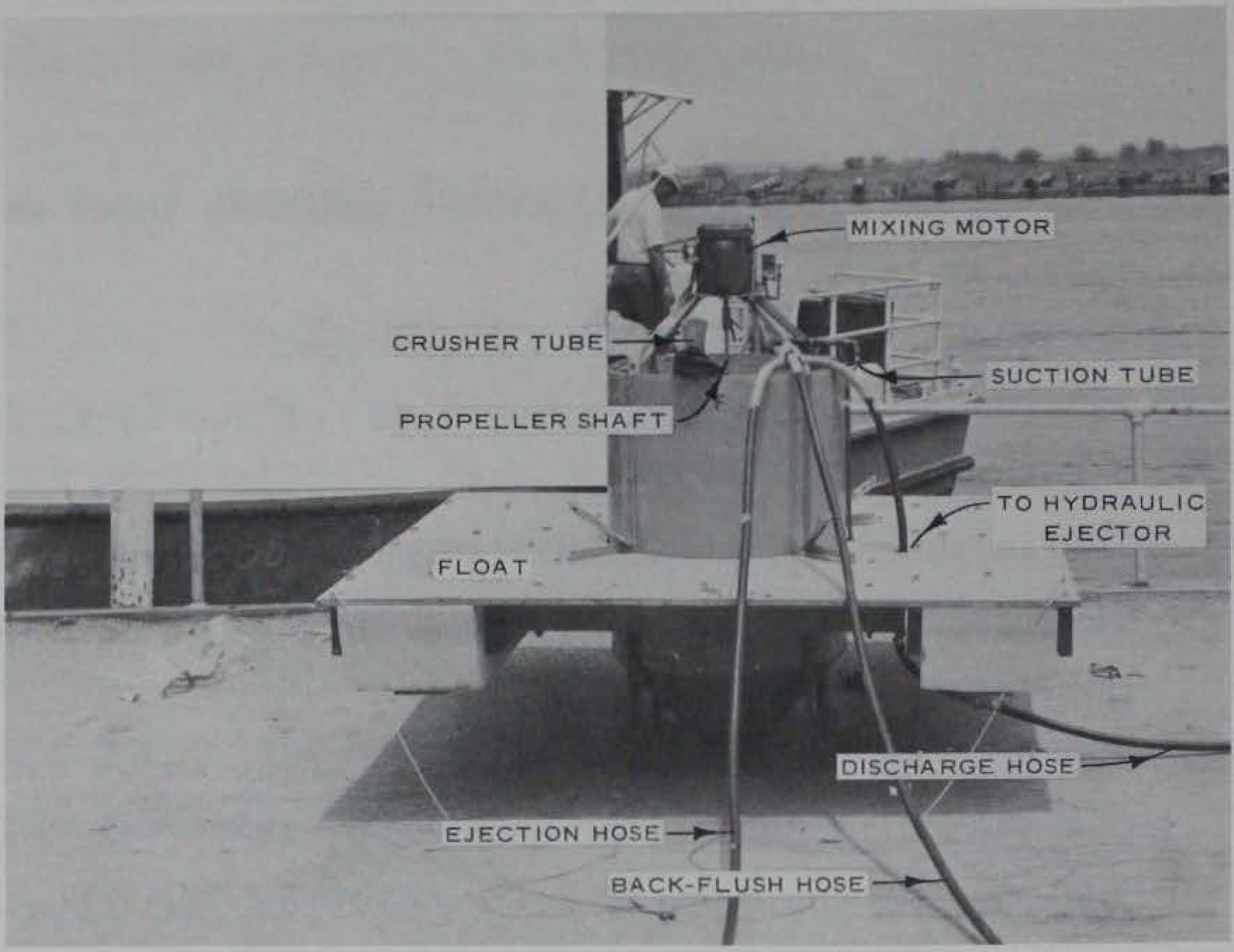

Fig. 1. Float-mounted mixing tank for sediment labeling

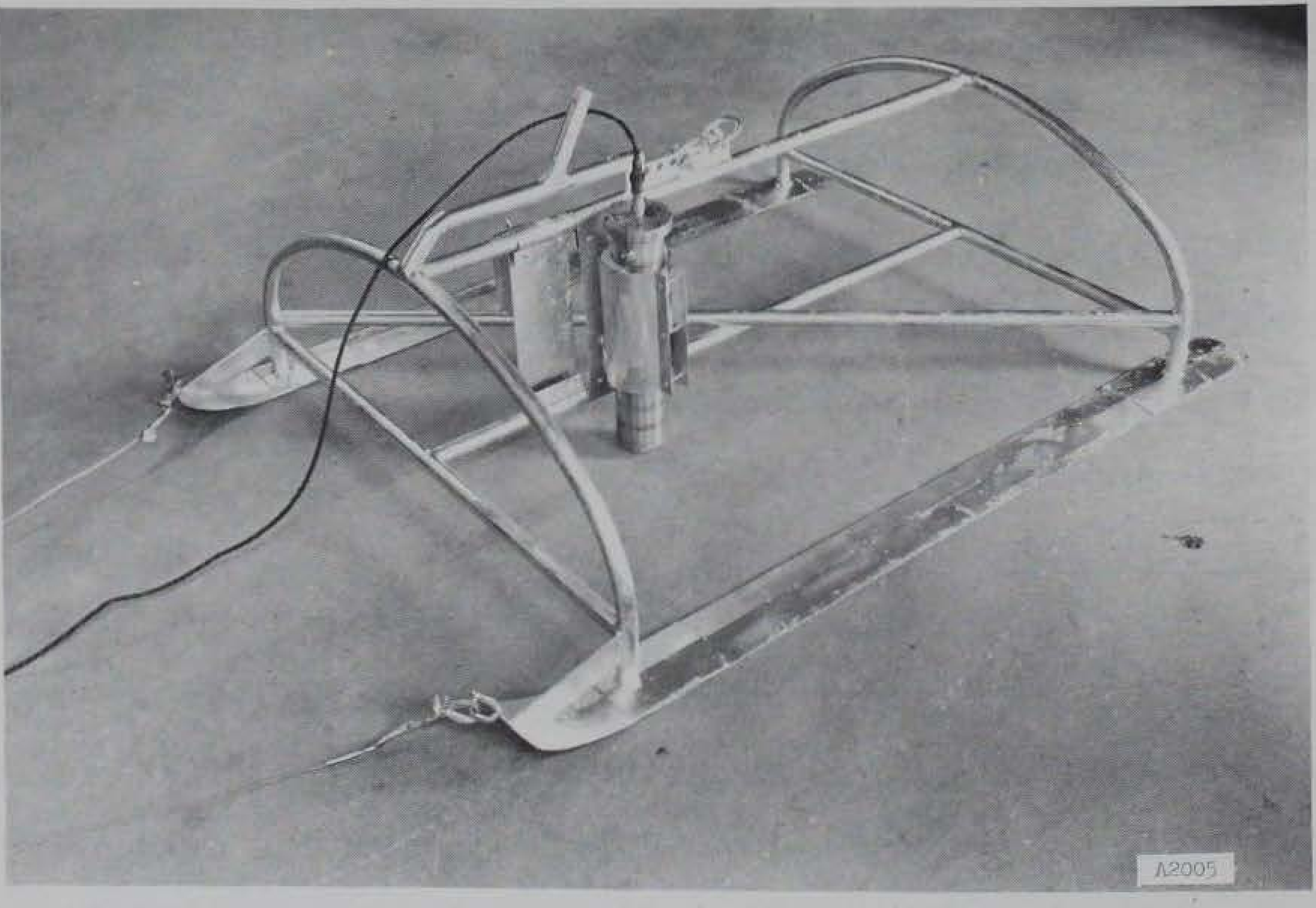

Fig. 2. Sled-mounted scintillation detector. Runners were about 5 ft long

designed and built by the University of California,[5] has a $gold^{198}$ sensitivity of 6000 counts per minute per microcurie per square foot. It converted light pulses generated in the scintillator to electrical pulses and amplified them for transmission to electronic equipment located on the boat. A small winch and boom mounted on the stern of the boat (fig. 3) were used to handle the sled.

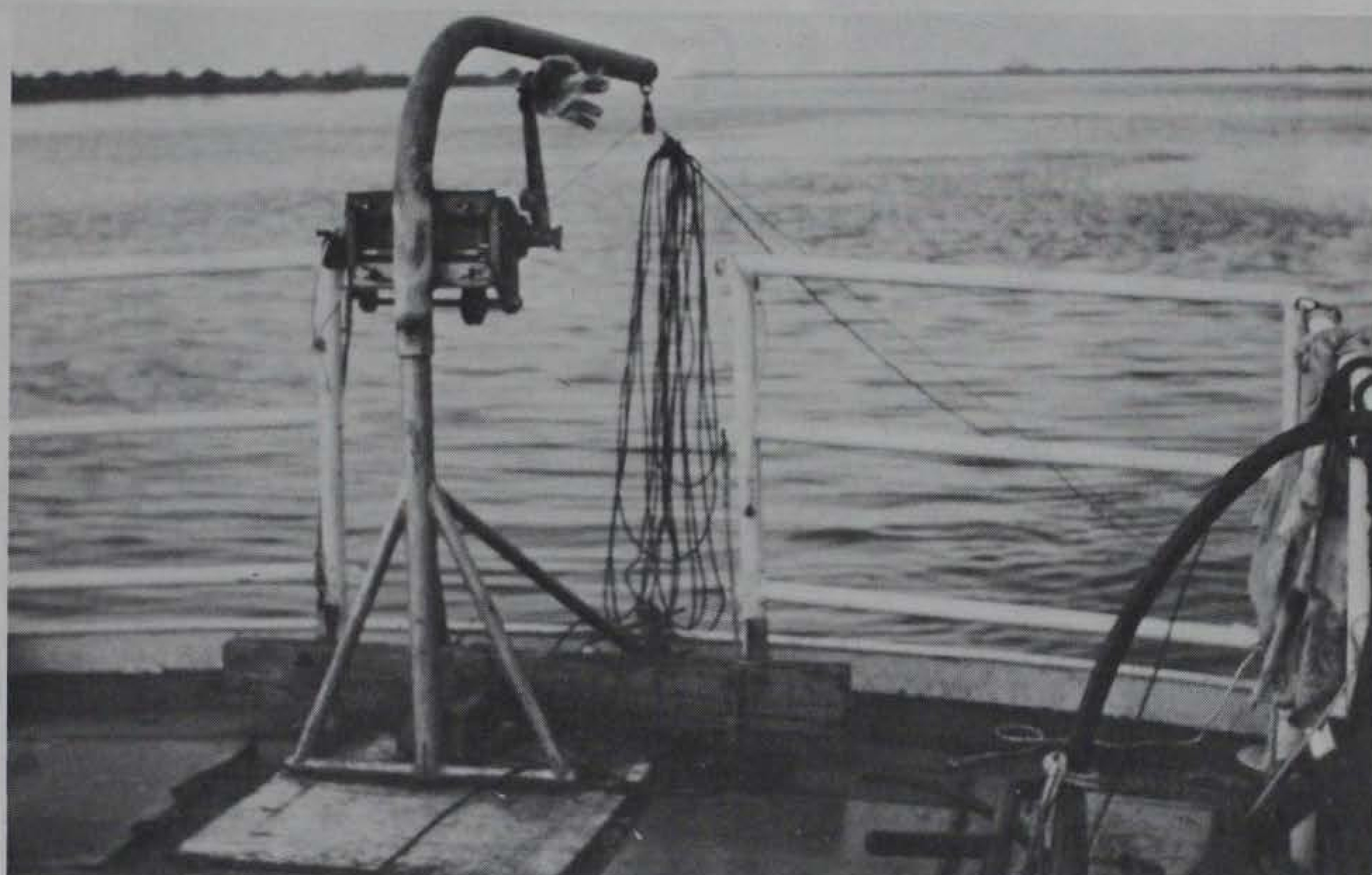

Fig. 3. Winch and boom for sled handling

14. The transmitted pulses were received by a Baird Atomic Model 250 Amplifier-Analyzer. (The amplifier and associated ratemeter and strip chart recorder are shown in fig. 4.) These pulses were proportional in amplitude to radiation energy. By daily calibrations with samples of $cobalt^{57}$, $cesium^{137}$, and $sodium^{22}$ having known characteristics, the pulse range corresponding to the energy of $gold^{198}$ was determined. The "window" of the analyzer was then adjusted to set the voltage span over which signals would be accepted for counting. Energies above or below the desired level were thereby rejected. The accepted signals were transmitted to the ratemeter. Controls on the ratemeter allowed integration of the signals over time intervals of 1, 3, 10, or 30 sec, and ranges of 100 to 100,000 counts per minute.

15. The strip chart recorder plotted the output from the ratemeter

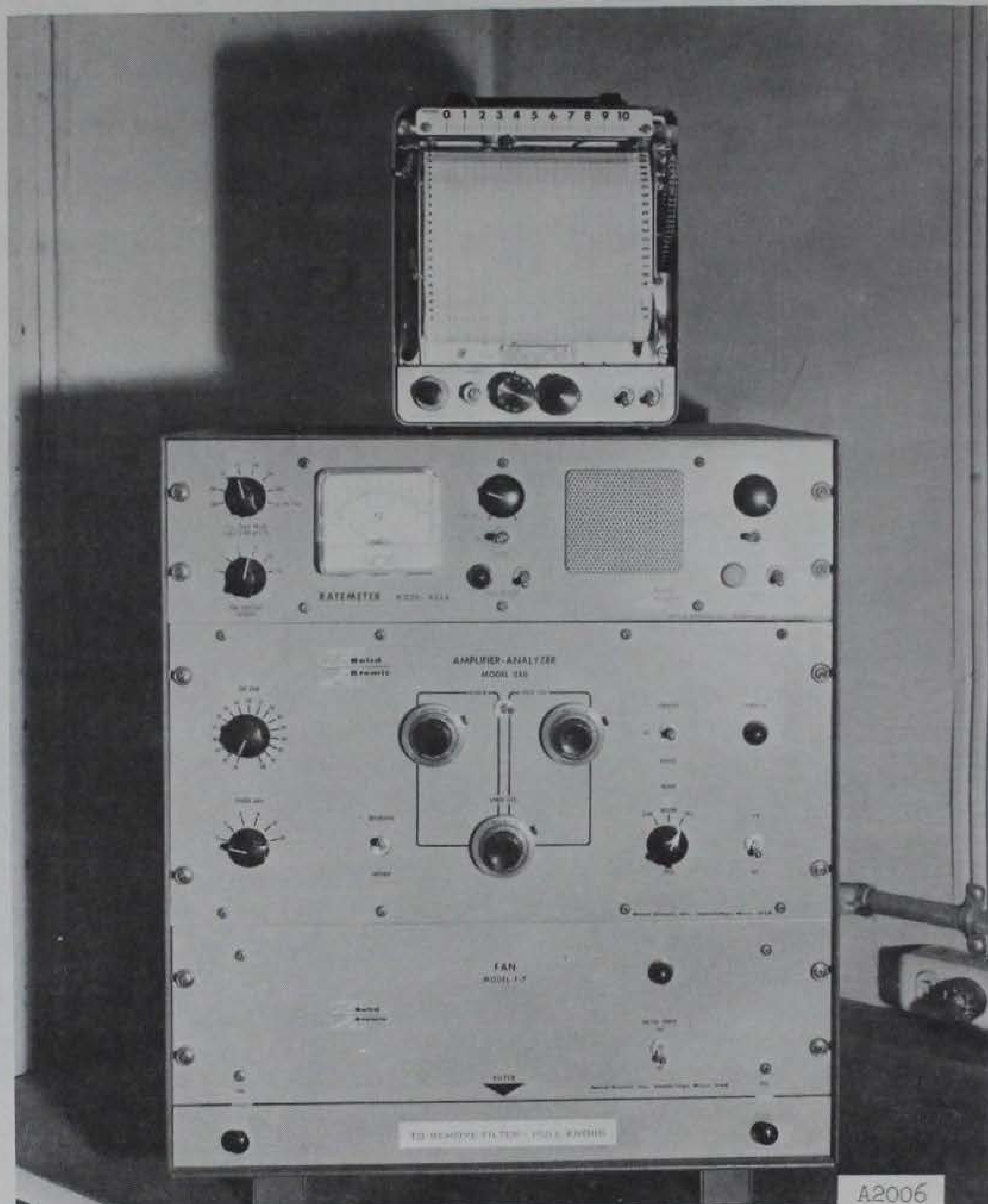

Fig. 4. Amplifier, ratemeter, and strip chart recorder

continuously at a chart speed of 1 in. per minute. Plate 2 presents a typical length of the strip chart.

Test Operations

Licensing

16. In order to use radioisotopes in the quantities required for these tests a license must be obtained from the U. S. Atomic Energy Commission. The license request is filed through the Office, Chief of Engineers, and the U. S. Army Surgeon General. To satisfy prelicense requirements a public hearing was conducted on 23 June 1967 in Houston,

Texas, to explain the tests and secure the approval of those concerned. A transcript of the hearing has been compiled by the Galveston District Office.

Local support

17. In conjunction with the tests, the Galveston District compiled considerable supporting data. Analysis and identification of bottom samples taken from the channel showed the sediments to be largely composed of clays, silts, and fine sands.

18. Daily records from the Texaco Dock, Morgan Point, and Kemah (see plate 1) tide gages were furnished. These data are shown in plate 3. Measurements of current velocities were made for periods of 24 hours on 21-22 and 28-29 August 1967. The velocities at 10-ft depth intervals on these dates are presented in plates 4 and 5, respectively.

19. Local climatological data were furnished by the U. S. Weather Bureau. These data for the period 1 August through 1 September 1967 are listed in table 1. Freshwater inflow from the major tributaries was provided by the U. S. Geological Survey. The tributaries, inflows, and gaging station locations are presented in table 2.

Background surveys

20. The first week of the test period was devoted primarily to background surveys. These were made to establish a datum level of activity for the tracer surveys. The discriminator circuits of the amplifier-analyzer were adjusted as previously discussed, to count radiation of the energy interval 0.31 to 0.45 Mev. Thus, radiations emitted from background sources having energies other than those passing through the gold "window" setting were not measured. Background count was reasonably uniform, averaging about 300 counts per minute at both test sites.

Sediment labeling and release

21. About 4 cu ft of well-screened sediment from the test area was placed in the mixing tank and towed to the release site. The isotope was picked up at a nearby dock in a small craft and delivered to the survey boat. Four-foot-long handling tongs were used to remove the bottle containing the isotope from the shipping container and place it in the crusher tube. The perforated crusher tube terminated within the slurry to provide

shielding for last-minute manipulation of the hoses and cables.

22. When on station, the bottle was crushed with a steel rod and the cable and hoses were extended to allow the tank to be towed about 40 ft behind the boat. The electric motor which drove the mixing propeller was then energized, and the slurry and isotope were allowed to mix for several minutes.

23. The activated sediment was then released through the hydraulic ejection system into a weighted discharge hose. Pressure was provided by a pump on the survey boat. The ejector drew a suction through the copper tube which extended to the bottom of the mixing tank. When the sediment release was complete, the tank was back-flushed and emptied several times to wash down any remaining activity. The back-flushing was accomplished by pumping directly into the copper tube. The hoses and cables were then disconnected at the survey boat, and the tank and accessories were towed away by a small craft.

24. Release 1 was made on 21 August and release 2 on 28 August. In each case the release was made in a perpendicular line across the channel. Plate 1 indicates the release site locations.

Sediment tracing

25. Sediment tracing was initiated immediately following release of the isotope. Each survey was conducted for a period of 5 days.

26. Survey runs were begun each day at a point determined to be outside the existing boundaries of the induced activity. A zigzag course was then followed through the channel until the detector was again outside of the activity. This procedure was repeated several times daily as time and weather conditions permitted. Activity encountered was continuously recorded as previously described. Several runs were also made on the shoulders of the channel and for short distances in tributaries.

27. The sled was occasionally pulled in to clean off debris which had collected on it. If the recorder activity reached a constant rate, the sled was checked. This was to ensure that mud or other material had not collected on the detector and "contaminated" it.

Navigation

28. Location of the survey boat was determined through the use of

simultaneous transit observations from stations along the channel. These stations were numerous at each test site because of the considerable distance required for the surveys. While two instrumentmen were fixing the boat's position, a third was usually being moved forward to a new station. Specially prepared charts were used with angles turned from known targets. Coordination of the fixes was obtained by maintaining radio contact between the instrumentmen and the plotters aboard the boat. An event marker pen was used on the strip chart recorder to mark the time of fix for later correlation and plotting (see plate 2).

Radiation safety

29. Film badges and pocket dosimeters were worn by all personnel concerned with the handling and releasing of the isotope. These operations also were monitored continuously using high- and low-range survey meters. The working area of the boat was monitored throughout the tests. Very slight contamination was occasionally detected and was removed by hosing generously with water. Dose rates were measured at distances of 1 and 5 meters from each unshielded bottle immediately prior to its placement in the crusher tube. Upon completion of the second release the mixing tank was submerged in water at a Corps of Engineers installation. This was to prevent exposure to the still slightly contaminated tank. Custody of the tank was released to the Galveston District Radiation Protection Officer.

30. Background readings were taken along the riverbanks and beach areas prior to the release of the activated sediment. These areas were then monitored during low tide so that exposed areas could be checked. No radiation above background was measured on either the banks or the beaches. The monitoring was performed with two Geiger instruments using the most sensitive full-scale range of each. These were 0.2 and 0.5 milliroentgen per hour.

Test Results

Data reduction

31. The daily radioactivity intensities presented in plates 6 and 7 have been corrected for background count and isotope decay. The decay

correction was made by referring all readings back to the time of release utilizing the equation:

$$I = I_o e^{-\lambda t}$$

where

I = recorded intensity, counts per minute

I_o = initial intensity, counts per minute

e = 2.718

λ = decay constant = $\frac{0.693}{T\frac{1}{2}}$ = 0.0107

$T\frac{1}{2}$ = half-life of gold^{198} = 64.8 hr[9]

t = time elapsed since release, hours

Therefore, the plotted activities (I_o) are:

$$I_o = Ie^{0.0107t}$$

Analysis

32. The results of the tracer tests are presented in plates 6-8, which indicate the apparent daily movement of the sediment following injection of the isotope. Plate 8 represents the average values from plates 6 and 7. Considerable upstream sediment movement is evident. Downstream movement is limited to about 1 mile. The accumulative daily sediment transport distances varied somewhat between the test sites. A comparison is presented as follows:

	Sediment Movement, Miles	
Day No.	Downstream Site (Site 1)	Upstream Site (Site 2)
1	3	2
2	4	6
3	5	7
4	6	7-1/4

33. The tide cycles shown in plate 3 indicate that the release at site 1 was made during a rising tide and that at site 2 at high tide. Current velocities at a depth of 41 ft are in an upstream direction most of the time during both flood and ebb conditions, as shown in plates 4 and 5. It is possible that this phenomenon would be even more pronounced if current measurements had been made nearer the channel floor at a depth of 45 ft.

34. Recorded activity along the zigzag course followed during most of the survey runs was usually highest at about the time the sled and detector crossed the center line of the channel. This is believed to be due to sediment moving to deeper water along the center of the channel bottom, the deeper section resulting from agitation by passing ships.

35. In an effort to determine the effect of passing ships on the sediment movement, the activity was measured along the deep center part of a length of the channel prior to and immediately following the passage of a ship. The test was conducted during a falling tide. The ship's draft was 22 ft. The measurements indicated an abrupt drop in average activity from about 700 to about 250 counts per minute, the latter count being lower than the average background value of about 300 counts per minute in that area. This sharp reduction in bottom activity is believed to have been due to the resuspension of bottom sediment by agitation from the passing vessel.

36. Because only one test run was made, further study of the resuspension of deposited sediment by passing ships was recommended. Eighteen additional sediment resuspension tests were conducted in the summer of 1968. The method was similar to the one described above except that water samples were collected through a suction hose and analyzed for sediment content in the Galveston District laboratory. The results of these tests are presented in table 3. Thirteen of the tests indicated an increase in sediment suspension following the passage of the large ships.

37. The activities measured on 31 August and 1 September 1967, as shown in plates 7 and 8, appear to be weak and dispersed. This is probably due to the smaller quantity of isotope received for the site 2 release (2.6 curies). Another contributing factor probably was dispersion

due to bottom currents and ship movements.

38. Tracing along the shoulders of the channel indicated very little sediment movement outside the channel. The most movement observed on the shoulder was in a westerly direction away from the point of release at site 1, but even there the significant activity was confined to within a few hundred feet from the channel. It had been anticipated that sediment might move into the 5-Mile Cut Channel (plate 1), but surveys in this channel revealed no activity above background.

Conclusions

39. Conclusions drawn from the results of the tracer investigations reported herein are as follows:

- a. In both of the channel reaches tested, sediment moves upstream at a relatively rapid and progressive rate. The only downstream movement appeared to take place immediately following the two tracer releases. Most of the sediment moves along the center line of the channel.
- b. Upstream currents near the channel bottom occur during falling tide as well as rising tide. The velocities of the upstream currents exceed those of the downstream currents, with the net result that upstream flow near the bottom strongly predominates.
- c. Once sediment is deposited on the channel bottom, very little of it moves out of the channel onto the shoulders or into tributaries.
- d. Ships navigating the channel appear to contribute significantly to resuspension of the deposited sediment. Once resuspended, the sediment moves progressively upstream under the influence of the predominant upstream currents at and near the bottom of the channel.
- e. The results of the tracer tests will provide a sound basis for developing the necessary procedures and techniques for properly simulating sediment movement in the Houston Ship Channel model.

f. The use of radioisotopes is an effective means of tracing sediment movement in a confined channel.

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8. R. S. Cummins, "Radioactive Sediment Tracer Tests, Cape Fear River, North Carolina," Miscellaneous Paper No. 2-649, May 1964, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

9. U. S. Department of Health, Education, and Welfare, "Radiological Health Handbook," PB 121784R, Sept 1960 (revised), Government Printing Office, Washington, D. C.

Table 1

Climatological Data,* 1 Aug-1 Sept 1967

Houston Ship Channel

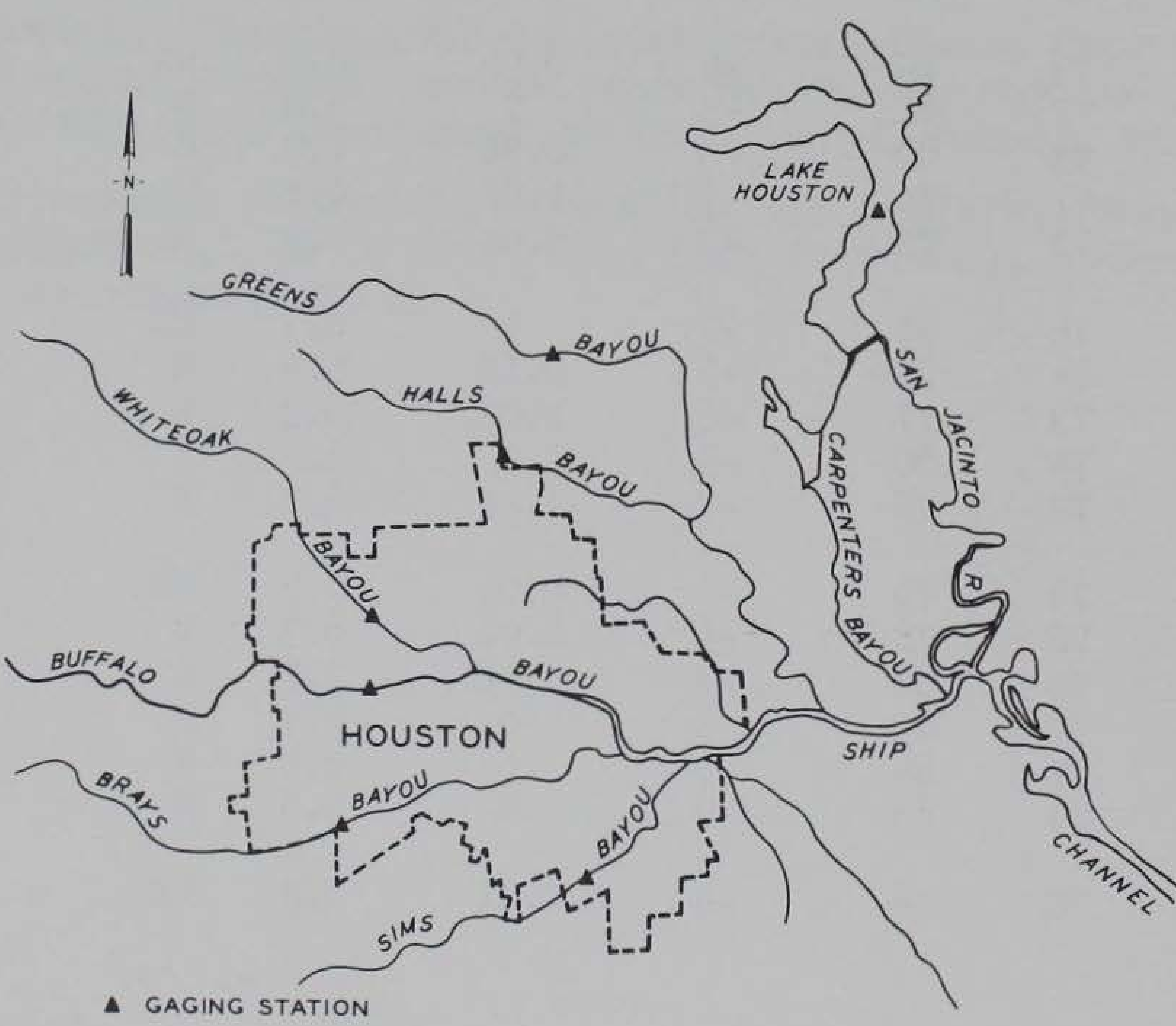
Date	Temperature, °F Maximum	Temperature, °F Minimum	Temperature, °F Average	Temperature, °F Departure from Normal Average	Total Precipitation in.	Wind Average Speed mph	Wind Prevailing Direction	Wind Fastest Mile Speed mph	Wind Fastest Mile Direction
Aug 1	86	81	84	0	0	12.8	SW	19	SW
2	87	82	85	+1	0	9.9	S	17	S
3	86	81	84	0	0	10.3	S	17	S
4	86	80	83	-1	0	7.8	S	14	SW
5	87	80	84	0	0	7.6	S	14	S
6	87	81	84	0	0	7.4	S	13	S
7	87	82	85	+1	0	7.5	S	14	S
8	87	82	85	+1	0	8.7	S	17	SW
9	88	82	85	+1	0	10.1	S	16	S
10	93	80	87	+3	0	7.5	SW	15	W
11	87	76	82	-2	0.53	10.9	NE	23	NE
12	82	68	75	-9	0	13.3	NE	23	NE
13	85	68	77	-7	0	8.2	NE	15	NE
14	85	75	80	-4	0	11.0	E	20	E
15	85	73	79	-5	0.10	10.0	SE	19	NE
16	84	73	79	-5	0.94	8.0	SE	17	SE
17	85	77	81	-3	T	8.8	S	19	SW
18	86	73	80	-3	0.36	7.7	S	17	NW
19	80	71	76	-7	1.82	6.1	E	18	S
20	80	72	76	-7	0.60	5.9	E	13	E
21	85	76	81	-2	0	6.3	SE	13	S
22	81	74	78	-5	0.10	5.2	E	12	S
23	81	73	77	-6	0.03	6.9	E	17	NE
24	84	75	80	-3	0	6.5	E	12	E
25	79	72	76	-7	1.18	6.7	E	16	NE
26	83	74	79	-4	0.01	5.5	NE	12	NE
27	80	76	78	-5	0.01	6.3	W	17	SW
28	83	76	80	-3	0.06	3.7	S	8	SW
29	89	77	83	0	0	5.4	N	13	SW
30	91	77	84	0	0	6.0	W	13	SW
31	86	79	83	0	0	5.5	S	11	S
Sept 1	83	72	78	-4	0.21	8.2	NE	17	NE

* Data were obtained at Station WBO, Galveston, Texas; latitude, 29°18'; longitude, 94°48'; ground elevation, 7 ft msl.

Table 2

Freshwater Inflow (cfs) to Houston Ship Channel

Tributary	August 1967									Sept
	21	22	23	24	25	28	29	30	31	1
Buffalo Bayou	59.0	81.0	88.0	168.0	348.0	227.0	188.0	133.0	149.0	82.0
Whiteoak Bayou	8.2	14.0	11.0	27.0	251.0	29.0	15.0	6.4	12.0	12.0
Brays Bayou	31.0	60.0	40.0	79.0	694.0	37.0	36.0	34.0	34.0	32.0
Sims Bayou	14.0	15.0	17.0	16.0	84.0	24.0	19.0	18.0	17.0	16.0
Greens Bayou	4.3	3.7	3.7	17.0	72.0	9.2	7.1	4.9	6.8	7.2
Halls Bayou	1.5	1.5	1.6	24.0	78.0	4.0	3.9	3.6	3.8	3.8
San Jacinto River*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carpenters Bayou*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



Tributary gaging stations

* Insignificant flow.

Table 3

Sediment Resuspension Due to Passage of Large Ships

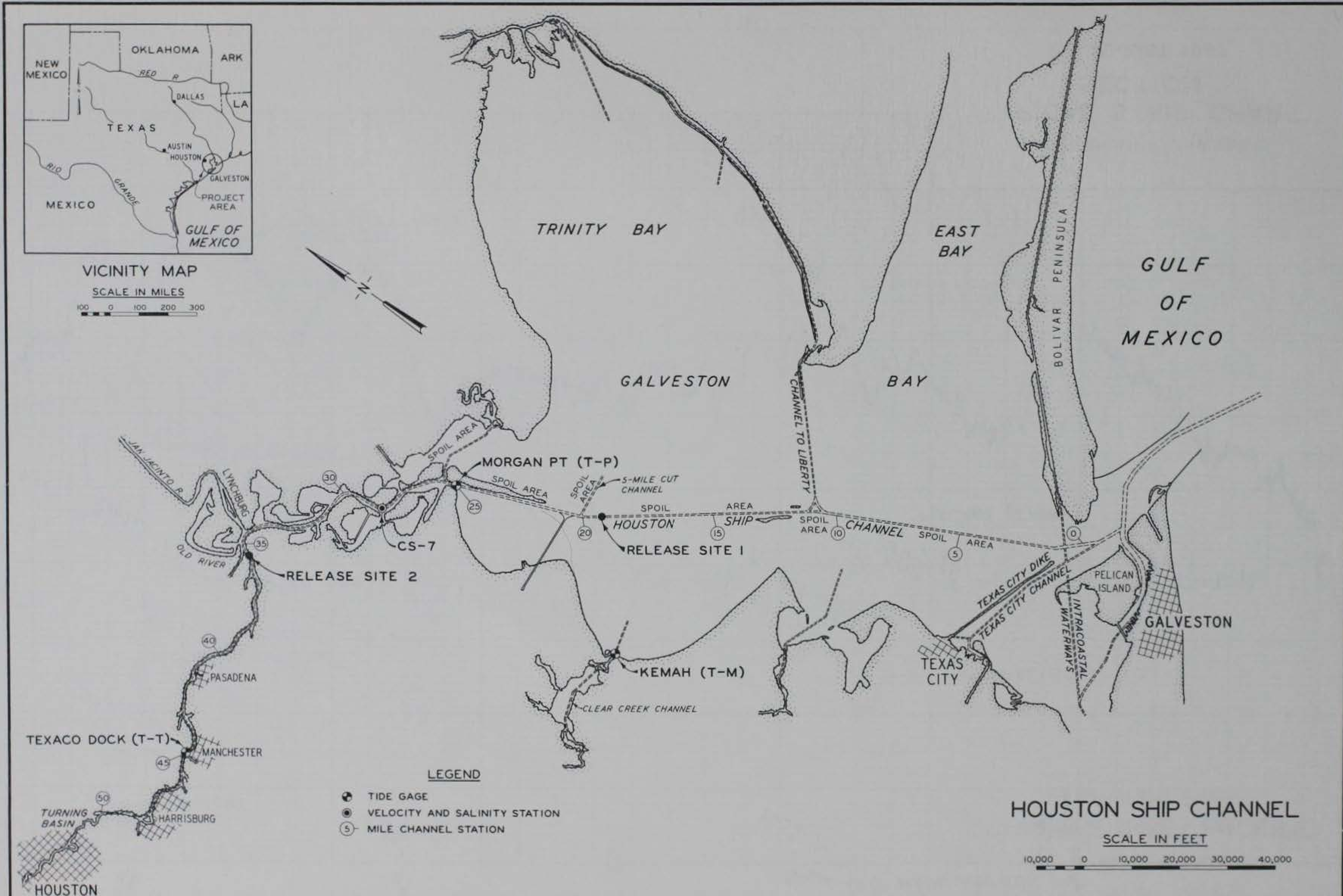
Houston Ship Channel

Test No.	Date	Ship's Heading	Ship's Draft ft	Tide Condition	Sample Distance from Bottom ft	Average Sediment Concentration* Before Ship's Passage	After Ship's Passage
1	6-25-68	Outbound	25	Ebb	10	0.306	0.328
2	6-25-68	Inbound	--	Slack	8	0.283	0.561
3	6-25-68	Outbound	31	Ebb	7	0.291	0.330
4	6-26-68	Outbound	32	Ebb	9	0.230	0.223
5	6-26-68	Inbound	18	Slack	8	0.269	0.342
6	6-26-68	Inbound	23 and 16**	Ebb	8	0.352	0.340
7	6-26-68	Outbound	34	Ebb	8	0.340	0.474
8	6-27-68	Outbound	34	Flood	8	0.349	0.609
9	6-27-68	Inbound	13	Flood	8	0.386	0.665
10	6-27-68	Inbound	20	Flood	7	0.366	0.351
11	6-27-68	Outbound	22	Flood	8	0.286	0.398
12	6-27-68	Outbound	24, 26, and 30†	Slack	8	0.421	0.403
13	8-15-68	Inbound	26	Ebb	8	0.021	0.029
14	8-15-68	Inbound	10	Slack	8	0.019	0.031
15	8-15-68	Inbound	20	Slack	7	0.032	0.048
16	8-15-68	Inbound	36	Ebb	8	0.028	0.205
17	8-15-68	Outbound	30	Ebb	7	0.103	0.089
18	8-16-68	Outbound	36	Ebb	6	0.039	0.082

* Concentration of sediment expressed as $\frac{\text{sediment wt (g)}}{\text{water volume (ml)}} \times 10^{-3}$.

** Two ships.

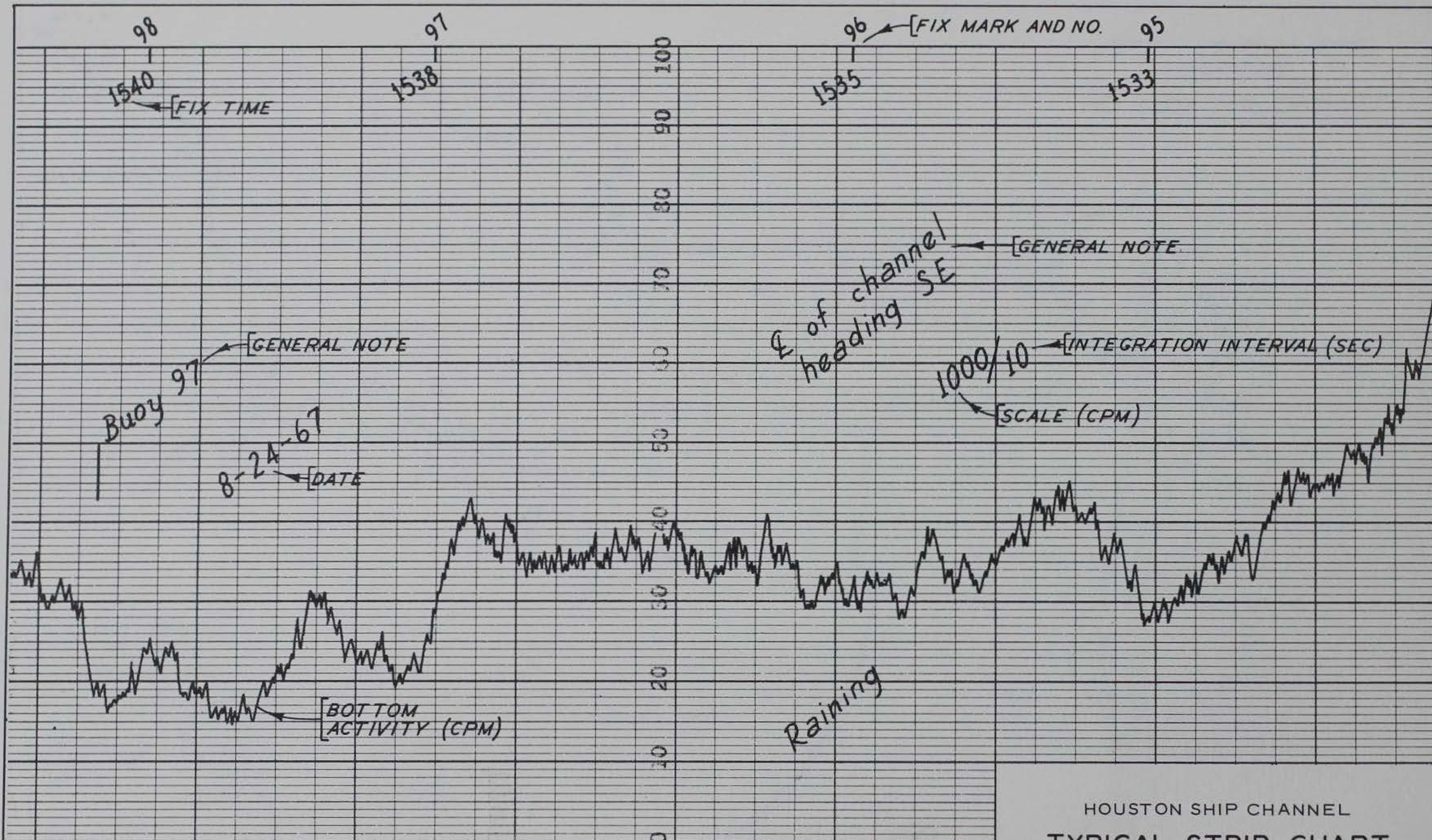
† Three ships.



HOUSTON SHIP CHANNEL
SCALE IN FEET
10,000 0 10,000 20,000 30,000 40,000
VICINITY MAP
SCALE IN MILES
100 0 100 200 300
OKLAHOMA
ARK
NEW MEXICO
RED R
DALLAS
LA
TEXAS
AUSTIN
HOUSTON
GALVESTON
RIO GRANDE
PROJECT AREA
MEXICO
GULF OF MEXICO
N
TRINITY BAY
EAST BAY
GULF OF MEXICO
BOLIVAR PENINSULA
GALVESTON
BAY
CHANNEL TO LIBERTY
SPOIL AREA
MORGAN PT (T-P)
5-MILE CUT CHANNEL
SAN JACINTO R
LYNCHBURG
OLD RIVER
CS-7
HOUSTON SHIP CHANNEL
RELEASE SITE 1
RELEASE SITE 2
TEXAS CITY DIKE
TEXAS CITY CHANNEL
INTRACOASTAL WATERWAYS
PELICAN ISLAND
GALVESTON
TEXAS CITY
KEMAH (T-M)
CLEAR CREEK CHANNEL
PASADENA
TEXACO DOCK (T-T)
MANCHESTER
HARRISBURG
TURNING BASIN
HOUSTON
LEGEND
TIDE GAGE
VELOCITY AND SALINITY STATION
MILE CHANNEL STATION

PLATE 1

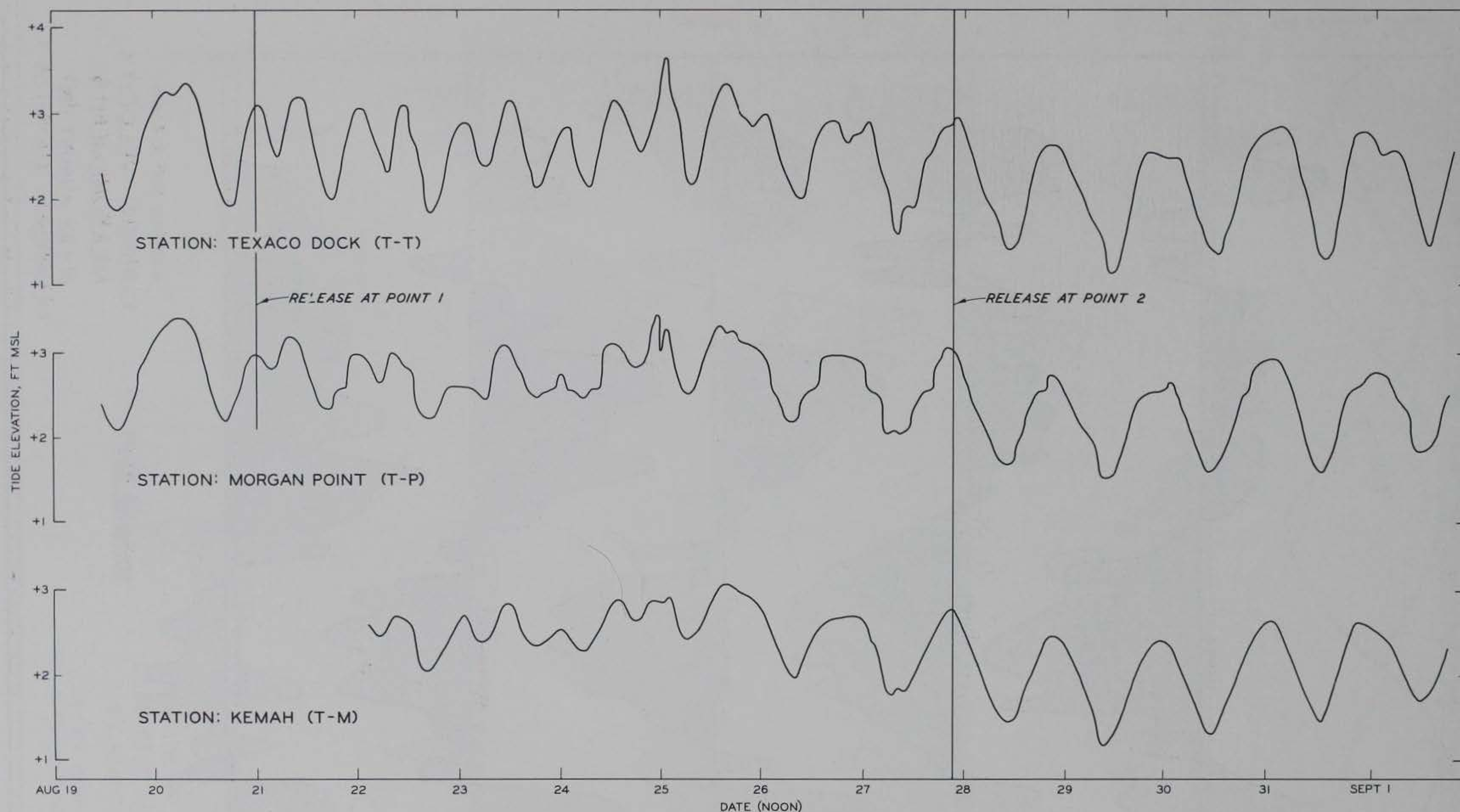
PLATE 2



HOUSTON SHIP CHANNEL

TYPICAL STRIP CHART SECTION

24 AUGUST 1967



HOUSTON SHIP CHANNEL

TIDE STATION ELEVATIONS

AUG 19 – SEPT 2, 1967

PLATE 3

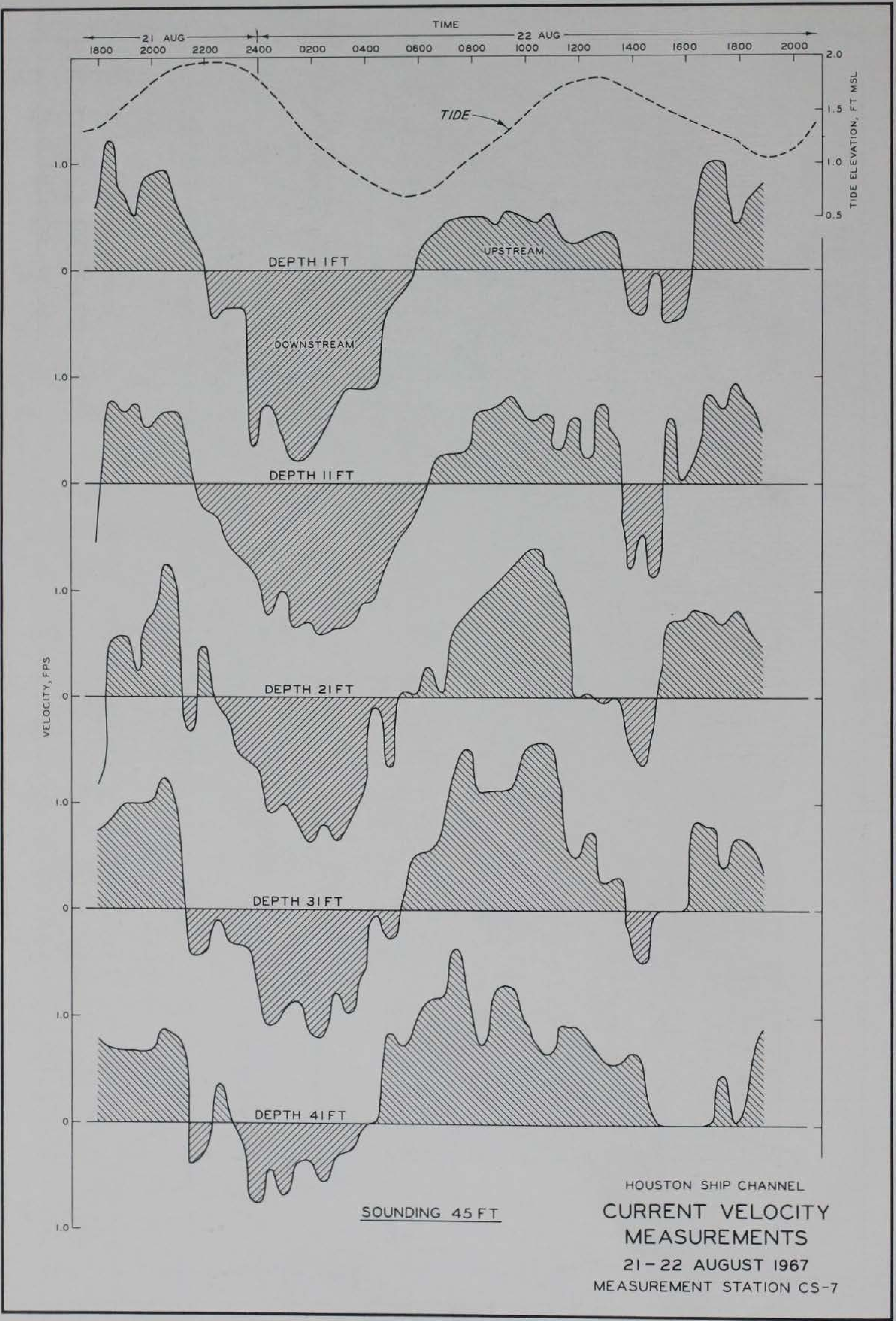
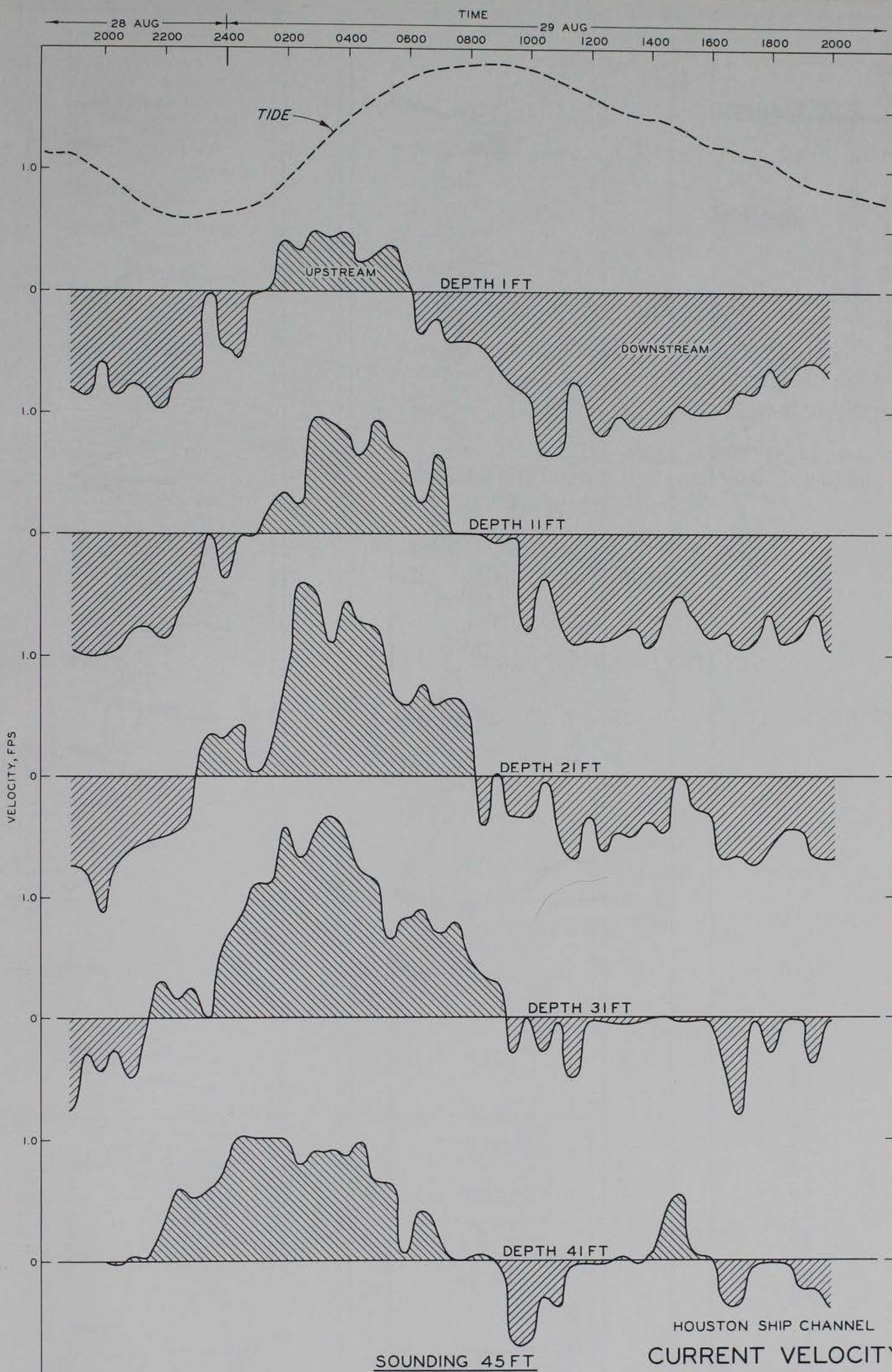

TIME
21 AUG
22 AUG
1800
2000
2200
2400
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
TIDE
TIDE ELEVATION, FT MSL
2.0
1.5
1.0
0.5
VELOCITY, FPS
UPSTREAM
DOWNSTREAM
DEPTH 1 FT
DEPTH 11 FT
DEPTH 21 FT
DEPTH 31 FT
DEPTH 41 FT
SOUNDING 45 FT
HOUSTON SHIP CHANNEL
CURRENT VELOCITY MEASUREMENTS
21 – 22 AUGUST 1967
MEASUREMENT STATION CS-7

PLATE 4



HOUSTON SHIP CHANNEL

CURRENT VELOCITY MEASUREMENTS

28-29 AUGUST 1967

MEASUREMENT STATION CS-7

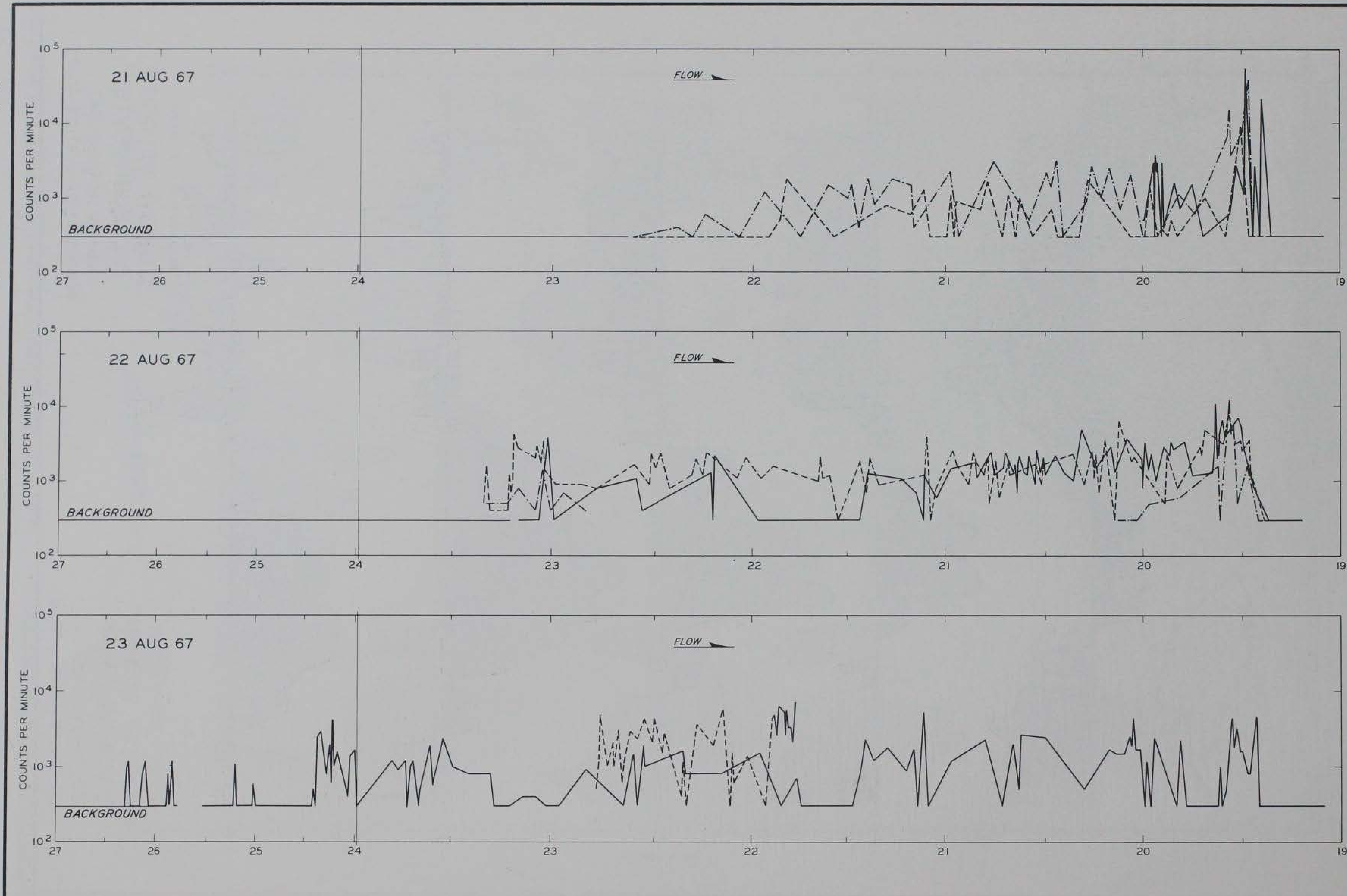
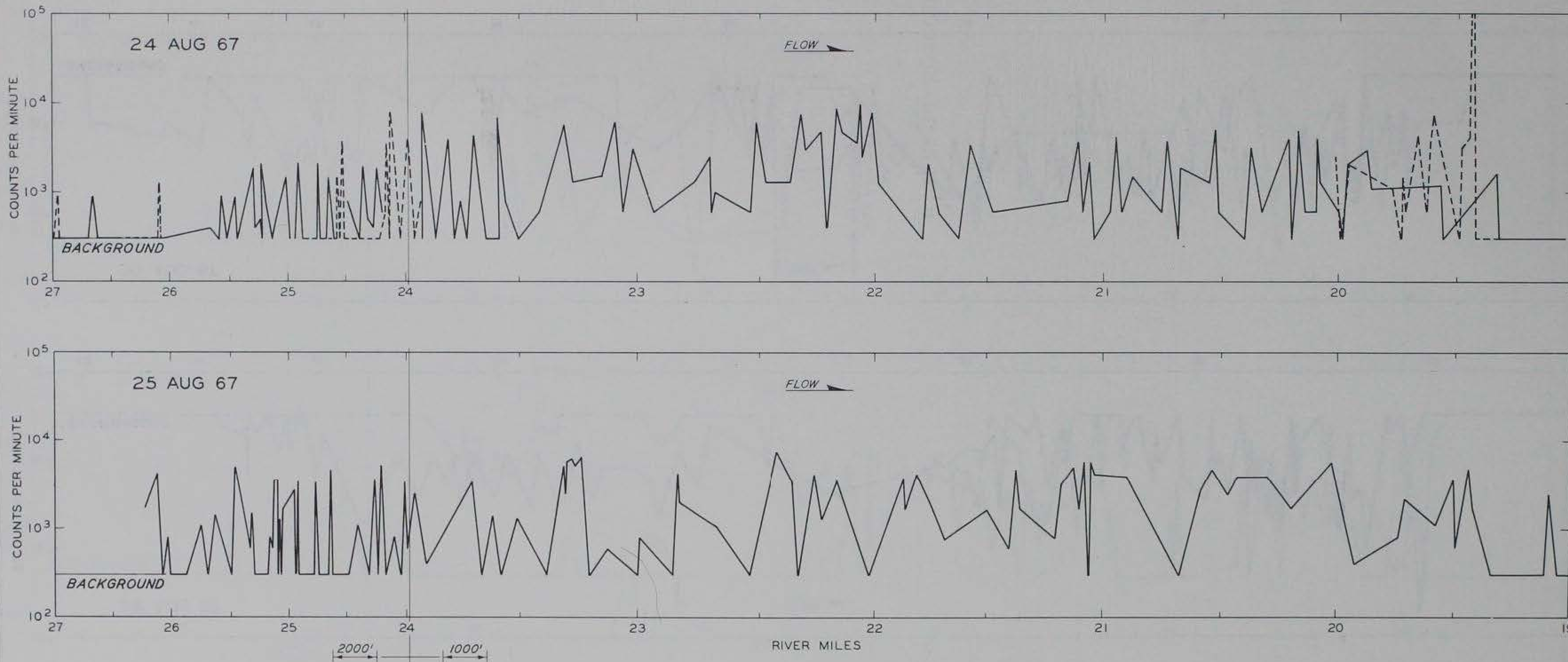


PLATE 6 (1 of 2 sheets)



NOTE: 1. ZIG ZAG COURSE FOLLOWED DURING EACH RUN.
2. MULTIPLE LINES INDICATE MORE THAN ONE RUN THAT DATE.

HOUSTON SHIP CHANNEL

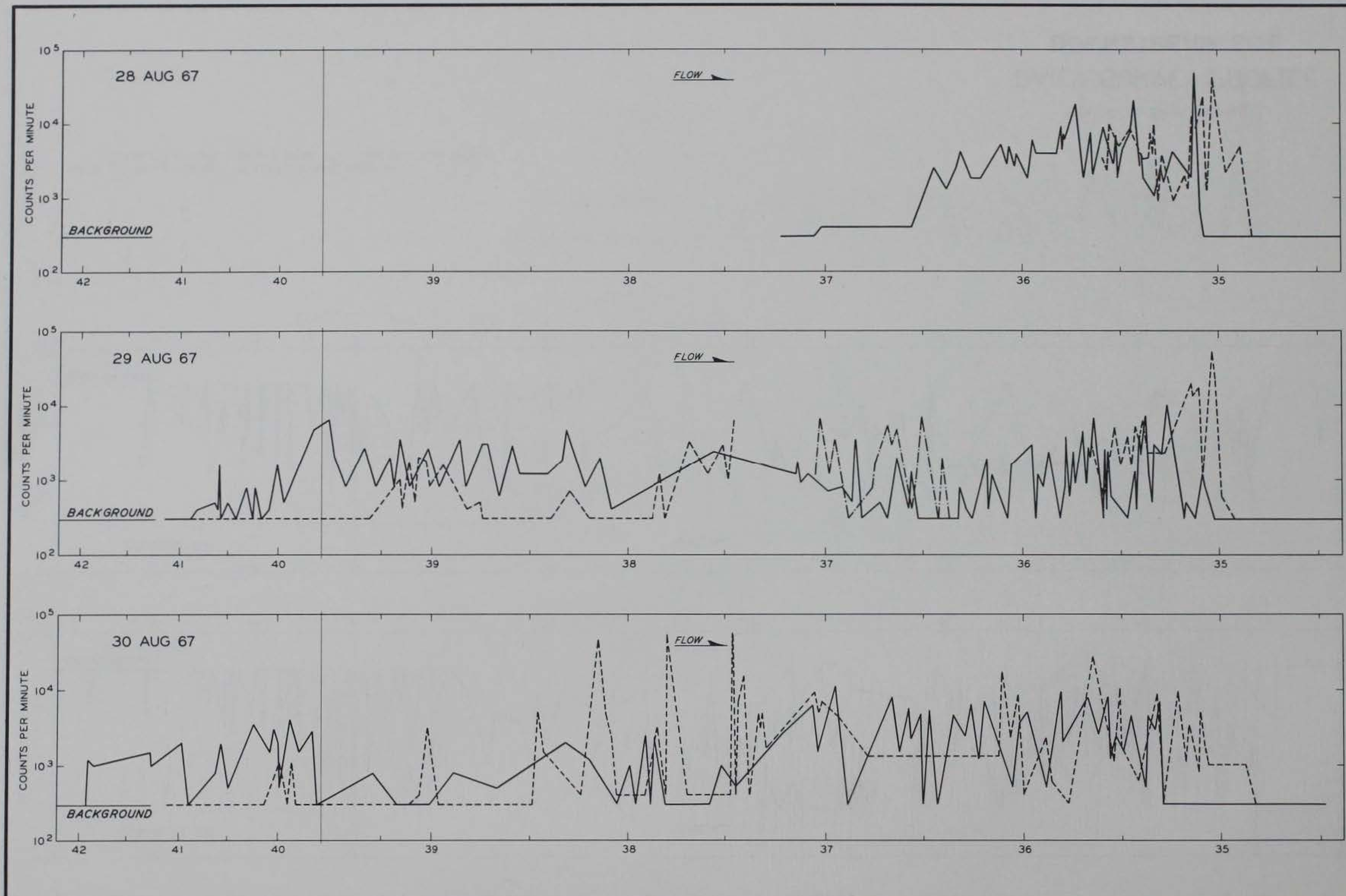
DAILY SURVEY PROFILE

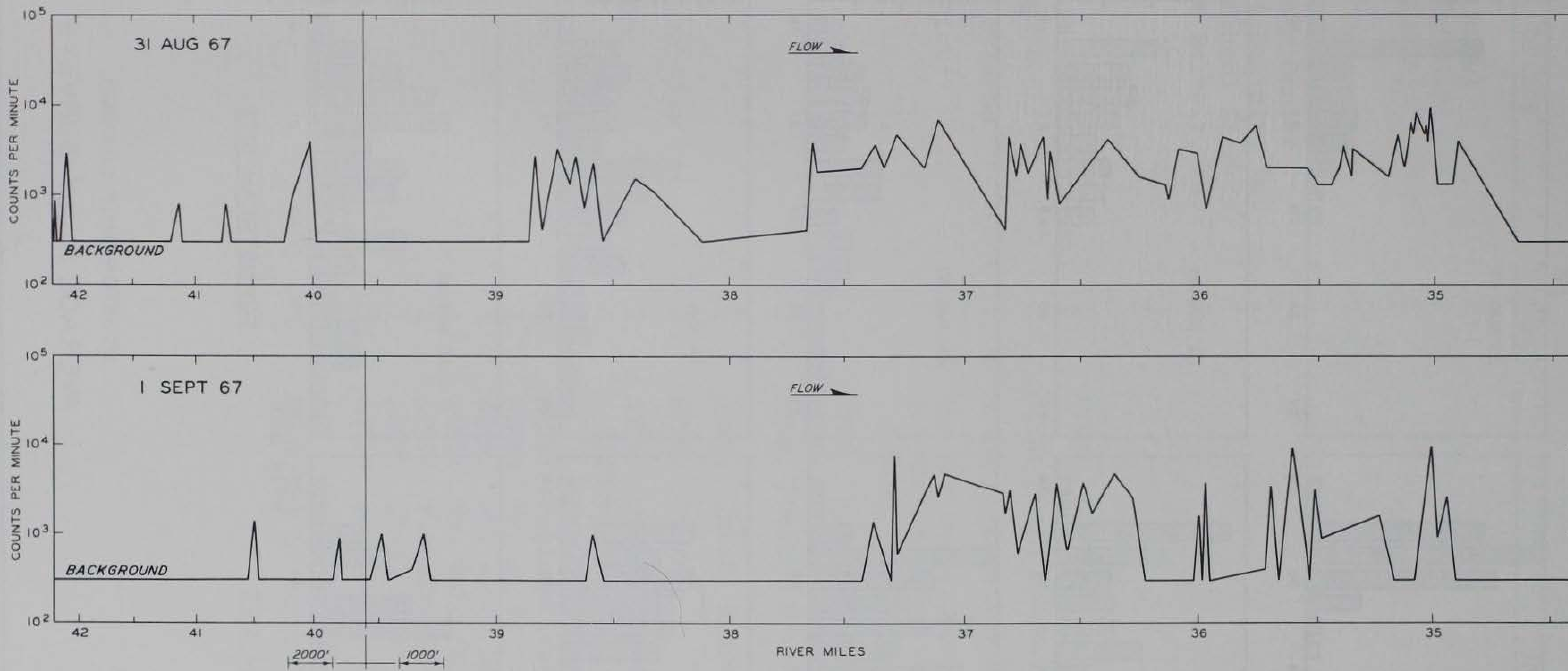
DOWNSTREAM SITE

PLATE 6 (2 of 2 sheets)

69400

PLATE 7 (1 of 2 sheets)



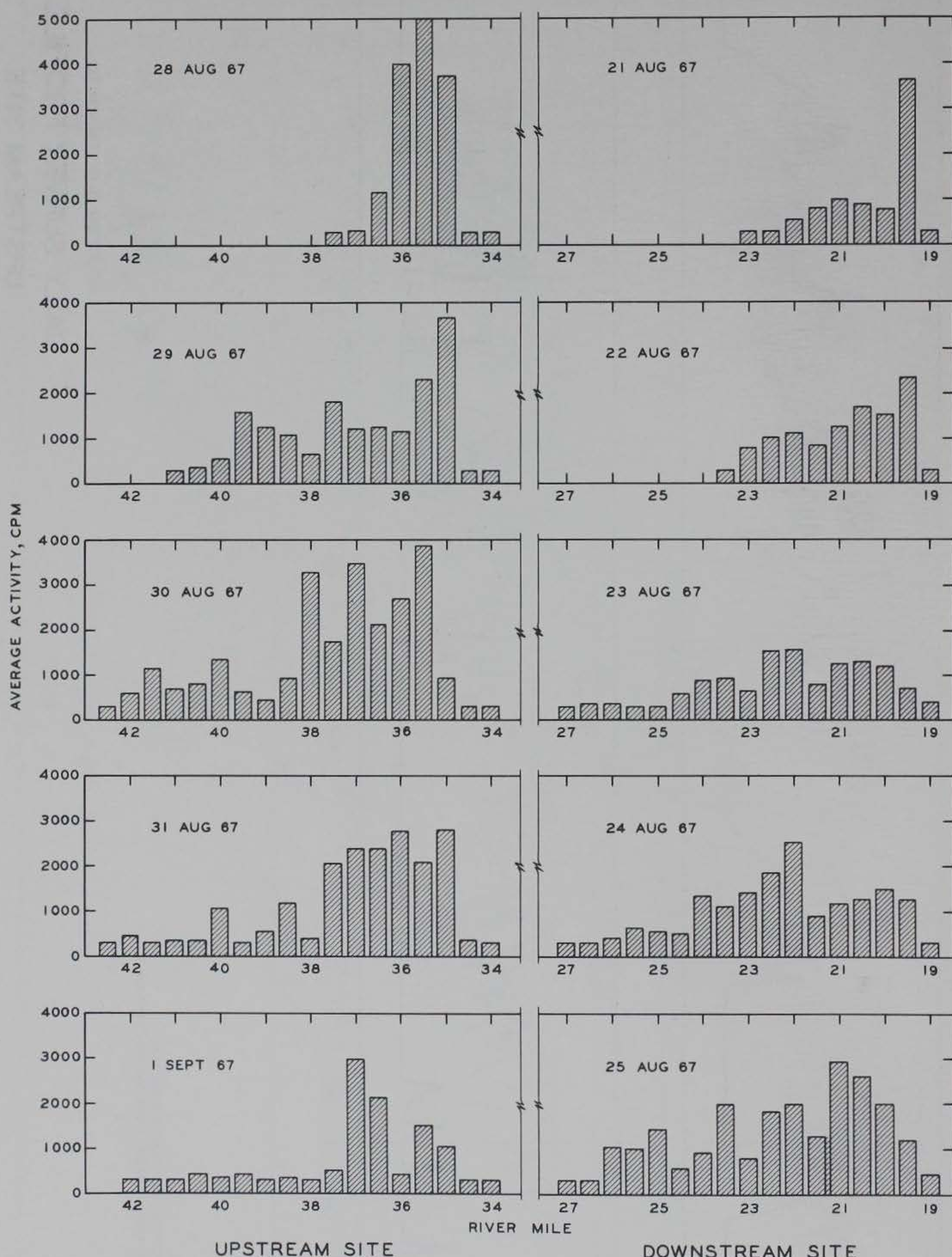


NOTE: 1. ZIG ZAG COURSE FOLLOWED DURING EACH RUN.
2. MULTIPLE LINES INDICATE MORE THAN ONE RUN THAT DATE.

HOUSTON SHIP CHANNEL

DAILY SURVEY PROFILE

UPSTREAM SITE



HOUSTON SHIP CHANNEL

AVERAGE DAILY SURVEYS

PLATE 8

Unclassified

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4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Final report

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13. ABSTRACT

Radioactive sediment tracer tests were conducted in the Houston Ship Channel to determine qualitatively the sediment movement in the channel. About 5 curies of the isotope $gold^{198}$ was thoroughly mixed with sediment samples from the channel, and the activated sediment was then deposited along the bottom at two locations. The results of tracing the deposits indicated that the activated sediment moved upstream for several miles. Activity was recorded downstream for only a short distance. Very little lateral movement out of the channel was detected.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Gold isotopes						
Houston Ship Channel						
Isotopic labeling						
Radioactive isotopes						
Sediments						
Sediment transport						
Tracers						

Unclassified

Security Classification