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A SUMMARY OF THE TEST PROCEDURES AND OPERATIONAL DETAILS OF AN OCEAN DUMPING POLLUTION MONITORING EXPERIMENT CONDUCTED OCTOBER 7, 1976

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A SUMMARY OF THE TEST PROCEDURES AND OPERATIONAL DETAILS OF AN OCEAN DUMPING POLLUTION MONITORING EXPERIMENT CONDUCTED OCTOBER 7, 1976

by

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SUMMARY

On October 7, 1976, a remote-sensor experiment was conducted by the National Aeronautics and Space Administration and the University of Delaware. The experiment was conducted at a sewage sludge dump site off the Delaware/Maryland coast. Two aircraft serving as remote-sensor platforms flew over the dump site during a sludge dump. One aircraft was a Lockheed P3-A that carried a Bendix Multispectral Scanner (M^2S), a Precision Radiation Thermometer (PRT-5), and two Zeiss cameras. The other aircraft was a Bell (Huey) UHI-B helicopter that carried a Tektronix Rapid Scanning Spectrometer (RSS) and a camera system containing four Hasselblad cameras. The operational objective of obtaining simultaneous sea-truth sampling with overpasses of the instrumented aircraft was met. Data from four sea-truth stations were collected concurrent with overpasses of the UHI-B, and data from 20 sea-truth stations were collected concurrent with overpasses of the P3-A. All sensors were operational and all produced good digital data. Description of the test site, sensors, sensor platforms, flight lines, sea-truth data collected, and operational chronology are presented.

INTRODUCTION

The Environmental Protection Agency (EPA) and the National Aeronautics and Space Administration (NASA) approved an Interagency Agreement[1] that established an effort to develop techniques for monitoring the dumping and discharging of chemical pollutants into coastal zone waters. Subsequently, NASA issued a grant[2] to the University of Delaware (UD) College of Marine Studies, to assist NASA in planning, conducting, and analyzing field tests of selected remote sensors which are candidates for monitoring instruments. On August 28, 1975, two remote-sensing experiments were conducted by NASA, UD, and cooperating commercial firms. One of the experiments was at an ocean/acid dump site approximately 56.3 kilometers (35 miles) east of Cape Henlopen, Delaware. The other experiment was at a river/organic waste and cooling tower water pipe discharge site on the Delaware River near Deepwater, New Jersey. The test procedures and operational details of these two experiments are documented in an NASA Technical Memorandum Report (ref. 1). On October 7, 1976, a remote-sensing experiment was conducted at an ocean/sewage sludge dump site located approximately 9.3 kilometers (5 n.mi.) south and 9.3 kilometers (5 n.mi.) east of the ocean/acid dump site. Simultaneous with the overflights of aircraft platforms carrying remote sensors, sea-truth samples were taken to support the calibration and analysis of the remote-sensor data. This report will document the operation of the October 7, 1976, experiment, and provide a reference of factual data to be used by principal investigators during experimental data analysis.

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[1] EPA/NASA IAG-0245, "Interagency Agreement between the National Aeronautics and Space Administration and the Environmental Protection Agency for the Purpose of Conducting Tests with Remote Sensors for Environmental Monitoring."

[2] NASA Grant NSF-1149, "Determination of Spectral Reflectance Signatures of Coastal Pollutants."

TEST CONDITIONS

Material and Location

The material dumped was approximately 3,785 cubic meters (1,000,000 gal.) of sewage sludge from a primary sewage treatment plant operated by the City of Philadelphia, Pennsylvania. The sludge was loaded into a barge at the treatment plant, and the barge was towed to the disposal site by tugboat. The disposal is conducted under permit monitored by Region III of the Environmental Protection Agency. The disposal site is east of Ocean City, Maryland, and is located and sized as shown in figure 1. The sludge is discharged through the bottom of the barge while the barge travels a figure eight pattern within the dump area. The waste plume resulting from the barge discharge on October 7, 1976, is the material investigated in the test.

Participants and Roles

The participants and their roles were as follows:

University of Delaware, College of Marine Studies

Supply and operate the United Detector Technology Scanning Spectroradiometer (SS)

SS data analysis

Assist in collection of sea-truth data

Chemical/physical analysis of sea-truth samples

Environmental Protection Agency

Coordinate sewage sludge dump schedule with the NASA test plan

City of Philadelphia, Pennsylvania

Provide sewage sludge sample for laboratory chemical and spectral studies

United States Coast Guard, Cape May, New Jersey

Provide ship and ship's crew for collecting sea-truth data

NASA, Langley Research Center

Coordinate all participants

Supply the Tektronix Rapid Scanning Spectrometer (RSS) flown on the Bell (Huey) UHI-B helicopter

Supply the Hasselblad camera package aboard the helicopter

Assist in collection of sea-truth data

Chemical/physical analysis of sea-truth samples

RSS data analysis

Multispectral Scanner (M^2S) data analysis

Laboratory chemical and spectral studies of sewage sludge sample

Laboratory analysis of particle size distribution

Wallops Flight Center

Supply the helicopter and flight crew

Process the Hasselblad camera film

Johnson Space Center

Supply the P3-A aircraft, crew, and all equipment aboard

Process and distribute the M^2S data

Process the Zeiss camera film

Aircraft, Watercraft, and Sensors

The following aircraft and sensors were utilized in the test:

Huey UH1-B (NASA 424)

The helicopter is stationed at the Wallops Flight Center and was staged from the municipal airport at Ocean City, Maryland. It carried a crew of two plus an observer. Sensors carried on the aircraft included a RSS (ref. 2) and a Hasselblad camera package of four cameras each equipped with a spectrally selective filter. The spectrometer is a laboratory instrument that was modified by NASA and adapted to an external attachment under the helicopter. The attachment can be seen in figure 2. Technical data describing the spectrometer and the camera package are given in tables I and II.

Lockheed P3-A (NASA 927)

The P3-A aircraft is stationed at the Johnson Space Center and was staged from the Langley Research Center, Hampton, Virginia. It carried a crew of eight plus an NASA Langley experimenter. Sensors carried on the aircraft included a M^2S radiometer (ref. 3), PRT-5 temperature sensor, and two Zeiss cameras. The M^2S, the PRT-5, and the two Zeiss cameras are described in tables III, IV, and V, respectively.

Coast Guard Cutter Point Franklin

The Point Franklin is a 25 meter (82 ft) Cutter operated by the Unites States Coast Guard out of Cape May, New Jersey. The vessel carried a ships crew of five. Six additional test crew personnel were aboard. The Point Franklin provided the platform for obtaining the sea-truth samples, and it served as the field command post. Instruments carried by the Point

Franklin and used for this test included a LORAN A navigation system and a UHF communication system.

Atmosphere and Sea

During the morning helicopter flight period (1020-1112 EDT), atmospheric conditions were bright Sun with considerable haze. The winds were variable and calm. The sea was calm without wind waves. Swells were 0.30 to 0.46 meter (1 to 1.5 ft) in height. During the morning P3-A flight period (1110-1307 EDT), atmospheric conditions were bright Sun with continued haze and high scattered clouds. The winds were from the south at velocities from 2.57 to 3.59 meters/second (5 to 7 knots).

During the afternoon coincident helicopter and P3-A flight period (1355-1555 EDT), the sky conditions included reduced brightness with a light overcast sky. Winds continued from the south at velocities from 2.57 to 3.59 meters/second (5 to 7 knots). Sea swells continued at 0.30 to 0.46 meter (1 to 1.5 ft) in height.

TEST OPERATIONS

Operational Objectives

The objectives during the morning helicopter flight period were to obtain as many sea-truth data stations as possible and have each data station occur simultaneously with overpasses of the helicopter with the RSS aboard. The objective during the morning P3-A flight period was to obtain a series of surface samples, evenly spaced over an approximate 9.3 kilometer (5 n.mi.) section of freshly discharged waste, as the aircraft, with scanner, made periodic overpasses of the area. The objective

during the afternoon concurrent helicopter and P3-A flight period, was to permit the helicopter to fly targets of opportunity while the sea-truth ship established another set of sampling stations in an older section of the plume in support of the P3-A flights.

Chronology

The day of the test was October 7, 1976. At 0500 EDT, the Cutter Point Franklin left the Cape May Coast Guard Station and proceeded to the dump site with a stop enroute to repair a navigation buoy. At 0835 EDT, the Tug Mary Ann reported initiation of the dump beginning at the northwestern corner of the dump area. The subsequent timing and pattern of the dump are shown in figure 3. The Point Franklin reached the southeast corner of the dump area at approximately 1015 EDT. The helicopter arrived over the Point Franklin at 1029 EDT, and helicopter station 1 was established immediately. The timing of the events that followed is given in table VI.

Data Stations and Samples Collected

Morning Flight Period

Four data stations were established in support of the morning helicopter flight period. Locations of the data stations were selected onsite based on plume conditions and timing considerations. The locations of stations 2 and 3 were recorded. The locations of stations 1 and 4 were calculated based on uniform ship speed and time between stations. The estimated accuracy is ±30.5 meters (100 ft). Station 1 was established outside the plume in typical ocean water. This station was to serve as

a baseline for reflected radiance measurements. Stations 2, 3, and 4 were to be established along the centerline of the plume; however, due to the plume being poorly visible from the sea-truth ship, it can only be stated with confidence that the stations were within the plume. Onsite data were recorded at each station, and water samples were collected at each station for laboratory analysis at a later date. Surface samples for laboratory analysis were taken with a hand cast plastic bucket, and depth samples were taken with a hand lowered oceanographic type sampling bottle. All samples were packed in ice immediately after collection and were retained on ice until arrival at the respective laboratory (Langley Research Center or University of Delaware). Onsite data and laboratory samples taken at the data stations are listed in table VII.

Twelve data stations were established in support of the morning P3-A flight period. The general locations of the data stations were selected prior to the test. The plan was to establish a series of surface stations along a continuous portion of the plume and make periodic overpasses of the portion being sampled. Specific locations of the data stations were selected onsite based on dump barge location and heading. The resulting locations are shown in their relative positions in figure 5. The age of the plume and each station when sampled is given in table VIII. Stations 4, 8, and 12 were established approximately 91 meters (300 ft) outside the plume boundaries to provide a typical ocean water baseline. Stations 1, 2, 3, 5, 6, 7, 9, 10, and 11 were established along the centerline of the plume. Centerline locations can be stated with confidence because the plume boundaries were clearly visible. The good plume visibility

resulted from beginning (Station 1) approximately 274 meters (900 ft) behind the actively dumping barge and following directly along the path. As can be seen in figure 5, the twelve stations were evenly spaced along a 7.8 kilometer (4.2 n.mi.) length of plume except for station 9. Station 9 was established specifically to include the plume crossing as a data station. The samples taken at each station were surface water samples collected by a plastic bucket hand cast alongside the Point Franklin as it crossed the centerline of the plume at minimum forward speed. All samples were packed in ice immediately after collection and were retained on ice until arrival at the Langley Research Center. Onsite data and laboratory samples taken at the data stations are listed in table VII.

Afternoon Flight Period

There were no data stations established in direct support of the afternoon helicopter flight period. The helicopter arrived at the dump site at 1355 EDT and flew targets of opportunity until 1444 EDT. Communications were established between the helicopter and sea-truth ship only to provide a monitor for safety of the helicopter during the flight period.

Eight data stations were established in support of the afternoon P3-A flight period. The general location of the data stations were selected prior to the test. The objective was to repeat the sequence accomplished during the morning flight period but to overfly and sample the other leg of the plume (oldest leg) forming the crossing "X." At the P3-A arrival time of 1430 EDT, however, none of the plume was visible to the crew aboard the sea-truth ship and only the leg sampled during the

morning period was clearly visible to the P3-A crew. With guidance provided by the P3-A crew, the sea-truth ship moved into the plume and sampled approximately the same section as that sampled during the morning flight period. Stations 13, 14, 15, 17,and 18 are thought to be in the plume. Their locations in reference to the plume, however, are not known with confidence, and are not plotted.

Additional Samples

During the return trip to Cape May, the sea-truth ship collected a 19 liter (5 gal) container of seawater from an area approximately 1.8 kilometers (1 n.mi.) west of the dump area. On the day following the test, 7.6 liters (2-gal) of undiluted sewage sludge taken from the same batch of material dumped on October 7, 1976, were obtained from the treatment plant in Philadelphia. These two samples were returned to the Langley Research Center for use in laboratory dilution and spectral analysis studies.

Flight Lines

Morning Flight Period

The flight lines for the morning helicopter stations were selected onsite to minimize Sun glint. As listed in table IX and shown on figure 4, a magnetic heading of 220 degrees was selected for all flight lines. All lines were flown at a speed of 4.2 meters/second (65 knots) and an altitude of 610 meters (2,000 ft). An additional flight line was flown at an altitude of 152.4 meters (500 ft) at station 1, the open ocean station. Flight lines were flown at the two different altitudes at station 1 to support the analysis of atmospheric effects on the reflected radiance. Flight lines at stations 2, 3, and 4 all crossed the plume

providing a continuous spectra radiance measurement from outside the plume, across the plume, to outside the plume again. The morning P3-A flight lines were slected onsite based on station locations, visibility of the plume, and the need to minimize Sun glint. The flight lines run in a south to north direction crossing the dump site and several legs of the plume. The times, altitudes, headings, and ground speed of the flight lines are given in table X. Sketches of the flight lines showing their positions relative to the stations are shown on figure 5.

Afternoon Flight Period

As stated in the Data Stations and Samples Collected discussions, the afternoon helicopter flight period was informal without planned data stations. Flight lines were at random. Data on the flight lines are given in table IX.

The afternoon P3-A flight lines were selected onsite based on visibility of the plume and the need to minimize Sun glint. At the time of the afternoon flight period, the plume boundaries were not visible to the sea truth ship and were poorly visible to the aircraft crew. The times, altitudes, headings, and ground speed of the flight lines are given in table X. A sketch of the flight lines is not presented because their locations with specific reference to the plume and sea truth stations are not known with confidence.

OBSERVATIONS AND RECOMMENTATIONS

As in most field tests that include complex operational procedures involving separate but related activity groups, deficiencies in procedures

are observed and unforeseen problems arise. Some of the more important deficiencies and problems encountered along with recommendations for overcoming them are discussed below for use in planning future similar tests. Several of the subjects discussed below are reiterations of those discussed after a previous ocean dump experiment (ref. 1).

Sea-Truth Ship Arrival and Stay Time

It is necessary to have the sea-truth ship on location during some portion of the actual dump period, in order that the timing and pattern of the dump sequence can be observed. During the subject dump sequence, the dump barge tracked a different dump pattern than expected. The new pattern required an onsite change in the location of the data stations supporting the morning helicopter flight period. If the actual dump pattern had not been observed and the sea-truth ship had cruised to the locations previously selected for the helicopter support stations, the entire helicopter flight period would have been lost.

Multiple Remote Sensor Platforms

Based on a recommendation from the previous test (ref. 1), separate morning flight periods were established for the helicopter and P3-A platforms. This action was most beneficial. It permitted the sea-truth ship and crew to support the needs of each platform independent of each other.

Communications

Good communications between the sea-truth ship and the remote sensor platforms are required. In addition, communications between the sea-truth ship and the tugboat towing the dump barge is desirable. This permits confirmation of dumping patterns and timing of important events in the

dump sequence such as beginning and endings, turnings at coordinates, and plume overlaps.

Visibility

During ocean dumps of some materials such as the highly visible, orange-red acid wastes studied during a previous experiment (ref. 1), the plume remains visible for several hours to crewmen aboard the sea-truth ship. The sewage sludge plume, however, was poorly visible to the sea-truth ship crew even when immediately behind the active dump barge. Upon leaving a section of the plume and attempting to locate a new section, detection becomes almost impossible. Several hours after a section of plume is created by a dump barge, the plume is not visible to the sea-truth ship crew even when located in the plume as confirmed by an overhead aircraft. The plume does, however, remain highly visible to overhead aircraft. This fact supports a statement that the remote sensor platforms must be prepared to guide the sea-truth ship in addition to fulfilling its flight duties. An alternate technique, if costs permit, is to use a small dedicated spotter aircraft equipped with a communication system capable of being tuned to the sea-truth ships frequency. The spotter aircraft can guide the sea truth ship relieving the remote sensor platform of the responsibility.

REFERENCES

1. Hypes, Warren D.; Ohlhorst, Craig W.: A Summary of the Test Procedures and Operational Details of a Delaware River and an Ocean Dumping Pollution Monitoring Experiment Conducted August 28, 1975. NASA TMX-74005, 1977.

2. Burke, Peter: Fast Scan Spectrometry Research/Development, April 1973, pp. 24-27.

3. Fisher, D.: Modular Multiband Scanner, M^2S. Bendix Document 1012, Rev. D, April 1974.

TABLE I. - RAPID SCANNING SPECTROMETER WITH 300 mm TAMRON LENS

Description

- Scanning spectrometer containing a Czerny-Turner monochromator w/2 gratings, a silicon-vidicon detector, and electronics

Spectral Characteristics

- Total range of 300 to 1100 nanometers
- Range with grating A (150 lines/mm)
  300 to 700, 400 to 800, 500 to 900, 600 to 1000, 700 to 1100 nanometers
- Range with grating B (1200 lines/mm)
  40 nanometer window variable from 300 to 1100 nanometers
- Resolution
  with grating A - 4.0 nanometers
  with grating B - 0.4 nanometers

Operational Characteristics

- Swath width of 14 meters (46 ft) at altitude of 609.6 meters (2,000 ft) with telephoto lens.
- Field of view - 1.3 degrees w/300 mm telephoto lens
- Instantaneous surface resolution - 14 meters (46 ft) x 0.9 meter (3 ft)

Data Characteristics

- Measures radiant energy at different spectral wave lengths
- Voltage output of analog signal stored on magnetic tape

Applications[1]

- Laboratory and low altitude determinations of spectral signatures

[1]Application by Langley Research Center. Consult manufacturer (Tektronix) for other applications.

TABLE II. - HASSELBLAD CAMERA PACKAGE

Camera	Focal length (millimeters)	Filter	Wave Length (nanometers)	Film Format (millimeters)	Film Type[1]
Hasselblad	40	5543 (green)[2]	540-580	70	2402 black/white
Hasselblad	40	5250 (blue-green)[2]	500-550	70	2402 black/white
Hasselblad	40	12 (yellow)[3]	500-700[4]	70	2402 black/white
Hasselblad	40	89B (near IR)[3]	690-900[4]	70	2424 black/white

Operational Characteristics

- Surface coverage - 419.1 meters (1.375 ft.)/304.8 meters (1,000 ft.) altitude
- Field of view - 88 degrees
- Instantaneous surface resolution - 0.38 meters (1.25 ft.) x 0.38 meters/304.8 meters altitude

[1]Kodak Film number

[2]Baird - automatic B-3 optical filter

[3]Kodak - Wratten optical filter number

[4]Cut-off by film characteristics

TABLE III. - MODULAR MULTISPECTRAL SCANNER

Description

- Imaging spectrometer optics with reflection grating dispersing element
- 10-band silicon detector array

Spectral Characteristics

- Range - 380 to 13,000 nanometers
- Bands -

1. 380 - 440	7. 660 - 700
2. 440 - 490	8. 700 - 740
3. 495 - 535	9. 760 - 860
4. 540 - 580	10. 970 - 1060
5. 580 - 620	Thermal. 8,000 to 13,000
6. 620 - 660	

Operational Characteristics

- Swath width of 2.4 x altitude
- Field of view - 120 degrees (100 active plus 20 for roll compensation)
- Instantaneous surface resolution - 0.8 meter (2.5 ft) x 0.8 meter/ 304.8 meters (1,000 ft) altitude

Data Characteristics

- Measures radiant energy in 10 wavelength bands
- Voltage output of analog signal stored on magnetic tape

Applications

- Determination of spectral signatures and temperatures of Earth surface features

TABLE IV. - PRECISION RADIATION THERMOMETER (PRT-5)

Description

- Thermal - infrared radiometer

Spectral Characteristics

- Total range of 800 to 1400 nanometers
- Single bandpass filter, use of full range as one band

Operational Characteristics

- Swath width of 10.7 meters (35 ft)/304.8 meters (1,000 ft) altitude
- Field of view - 2 degrees
- Instantaneous surface resolution - Circle with diameter of 10.7 meters/304.8 meters altitude

Data Characteristics

- Measure thermal - infrared radiations
- Temperature resolution - ±0.5 degrees C
- Output of 0 to 5 volts analog multiplexed and recorded on magnetic tape

Applications

- Provides a target temperature reference

TABLE V. - ZEISS CAMERA PACKAGE

Camera	Focal Length (Inches)	Film			Shutter Speed (Seconds)	F Stop	Filter Type	Wavelength (nanometers)
		Format (Inches)	Type	Emulsion				
Zeiss 1	6	9 x 9	SO-397 Aerial Color	42-1	1/150	Automatic	2A	400-700
Zeiss 2	6	9 x 9	2443 Color IR	206-2	1/125	Automatic	12	510-900

TABLE VI. - TIMING OF EVENTS

Time (EDT)	Event
Unknown, 10-6-76	Tug and barge depart Philadelphia, Pennsylvania
0500, 10-7-76	Cutter Point Franklin depart Cape May, New Jersey
0835	Sewage sludge dump begin
0950	Helicopter depart Ocean City, Maryland
1015	Point Franklin arrive test site
1020	Helicopter arrive test site
1029	Helicopter data station 1
1035	P3-A depart Langley Research Center
1046	Helicopter data station 2
1055	Helicopter data station 3
1109	Helicopter data station 4
1110	P3-A arrive test site
1112	Helicopter depart test site
1147	Helicopter arrive Ocean City, Maryland
1150	P3-A data station 1
1155	P3-A data station 2
1200	P3-A data station 3
1205	P3-A data station 4
1210	P3-A data station 5
1215	P3-A data station 6
1220	P3-A data station 7
1225	P3-A data station 8
1227	P3-A data station 9
1230	P3-A data station 10
1235	P3-A data station 11
1240	P3-A data station 12
1307	P3-A depart test site
1319	Helicopter depart Ocean City, Maryland
1320	P3-A arrive Wallops Flight Center
1340	Sewage sludge dump end
1355	Helicopter arrive test site
1410	P3-A depart Wallops Flight Center

TABLE VI. - CONCLUDED

Time (EDT)	Event
1430	P3-A arrive test site
1444	Helicopter depart test site
1450	P3-A data station 13
1455	P3-A data station 14
1500	P3-A data station 15
1504	P3-A data station 16
1514	Helicopter arrive Ocean City, Maryland
1536	P3-A data station 17
1538	P3-A data station 18
1545	P3-A data station 19
1555	P3-A data station 20
	P3-A depart test site
1600	Point Franklin depart test site
1625	Collect ocean water sample
1630	P3-A arrive Langley Research Center
1945	Point Franklin arrive Cape May, New Jersey

TABLE VII. - ONSITE DATA AND SAMPLE COLLECTED AT DATA STATIONS

Data Station Number		Onsite Data Collected[1]												Samples[2] Collected	
		Wind Speed	Wind Direction	Sea State	Sky Conditions	Downwelling Irradiances in Air	Secchi Depth	pH	Conductivity	Salinity	Surface Temperature	Transmissivity Surface	Transmissivity 5-Meter Depth	Surface	5-Meter Depth
Helicopter	1	●	●	●	●	-	-	●	●	●	●	-	-	●	●
	2	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	3	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	4	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Aircraft Morning Flight	1	●	●	●	●			●						●	
	2	●	●	●	●			●						●	
	3	●	●	●	●			●						●	
	4	●	●	●	●			●						●	
	5	●	●	●	●			●						●	
	6	●	●	●	●			●						●	
	7	●	●	●	●			●						●	
	8	●	●	●	●			●						●	
	9	●	●	●	●			●						●	
	10	●	●	●	●			●						●	
	11	●	●	●	●			●						●	
	12	●	●	●	●			●						●	
Aircraft Afternoon Flight	13	●	●	●	●			●						●	
	14	●	●	●	●			●						●	
	15	●	●	●	●			-						●	
	16	●	●	●	●			-						●	
	17	●	●	●	●			●						●	
	18	●	●	●	●			●						●	
	19	●	●	●	●			-						●	
	20	●	●	●	●			-						●	

[1] A dash (-) indicates data collection planned but not completed. Open spaces indicate collection not planned.

[2] Samples analyzed for: particle size distribution, total suspended solids, Nitrates/Nitrites, Phosphates, Aluminum, Iron, Lead, Zinc.

TABLE VIII. - PLUME DISCHARGE AND SAMPLING TIMES AT STATION LOCATIONS

Station		Time Discharged	Time Sampled	Age of Plume[1] When Sampled (Hours:Minutes)
Helicopter	1	N/A[2]	1029	N/A
	2	1040	1046	0:06
	3	1037	1055	0:18
	4	1033	1109	0:36
Aircraft Morning Flight	1	1127	1150	0:23
	2	1132	1155	0:23
	3	1139	1200	0:21
	4	N/A	1205	N/A
	5	1149	1210	0:21
	6	1154	1215	0:21
	7	1159	1220	0:21
	8	N/A	1225	N/A
	9	1208	1227	0:19
	10	1211	1230	0:19
	11	1216	1235	0:19
Aircraft Afternoon Flight	12	N/A	1240	N/A
	13	1228	1450	2:22
	14	1221	1455	2:34
	15	1215	1500	2:45
	16	N/A	1504	N/A
	17	1209	1536	3:27
	18	1208	1538	3:30
	19	1154	1545	3:51
	20	1136	1555	4:19

[1]Calculated age based on recorded station times and barge discharge times.
[2]Not Applicable, stations planned outside of plume boundaries.

TABLE IX. - HELICOPTER FLIGHT LINES

Location	Time (EDT) At Station	Altitude		Magnetic Heading (Degrees)	Ground Speed (Knots)
		Meters	Feet		
Morning Flight Period					
Station 1, Line 1	1025	610	2,000	220	65
Station 1, Line 2	1028	610	2,000	220	65
Station 1, Line 3	1031	152	500	220	65
Station 1, Line 4	1033	152	500	220	65
Station 2, Line 1	1041	610	2,000	220	65
Station 2, Line 2	1044	610	2,000	220	65
Station 3, Line 1	1054	610	2,000	220	65
Station 3, Line 2	1057	610	2,000	220	65
Station 4, Line 1	1108	610	2,000	220	65
Station 4, Line 2	1111	610	2,000	220	65
Afternoon Flight Period					
Open Water	1338	610	2,000	102	80
Open Water	1340	610	2,000	102	80
Leg AD[1]	1357	610	2,000	080	65
Corner D	1400	610	2,000	180	65
Leg CD	1404	610	2,000	070	65
Leg CD	1407	610	2,000	070	65
Not Recorded	1418	610	2,000	110	65
Not Recorded	1420	610	2,000	285	65
Not Recorded	1425	610	2,000	035	65
Not Recorded	1429	610	2,000	205	65
Not Recorded	1432	610	2,000	095	65
Center Crossing	1435	610	2,000	040	65
Corner A	1443	610	2,000	325	65

[1] Letter designations A, B, C, and D refer to the coordinate labels established in Figure 3.

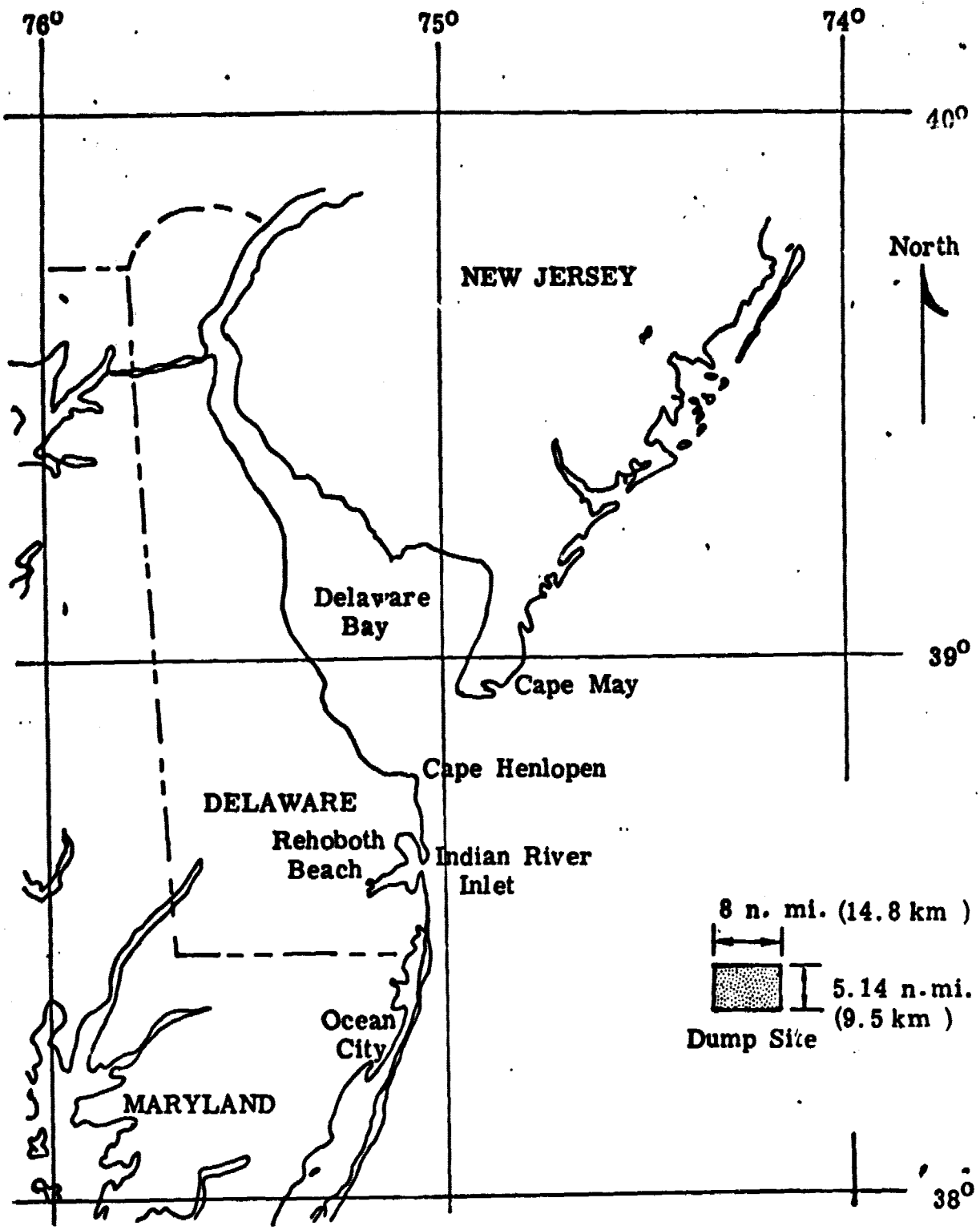

Figure 1. - Location and Size of Sewage Sludge Dump Site

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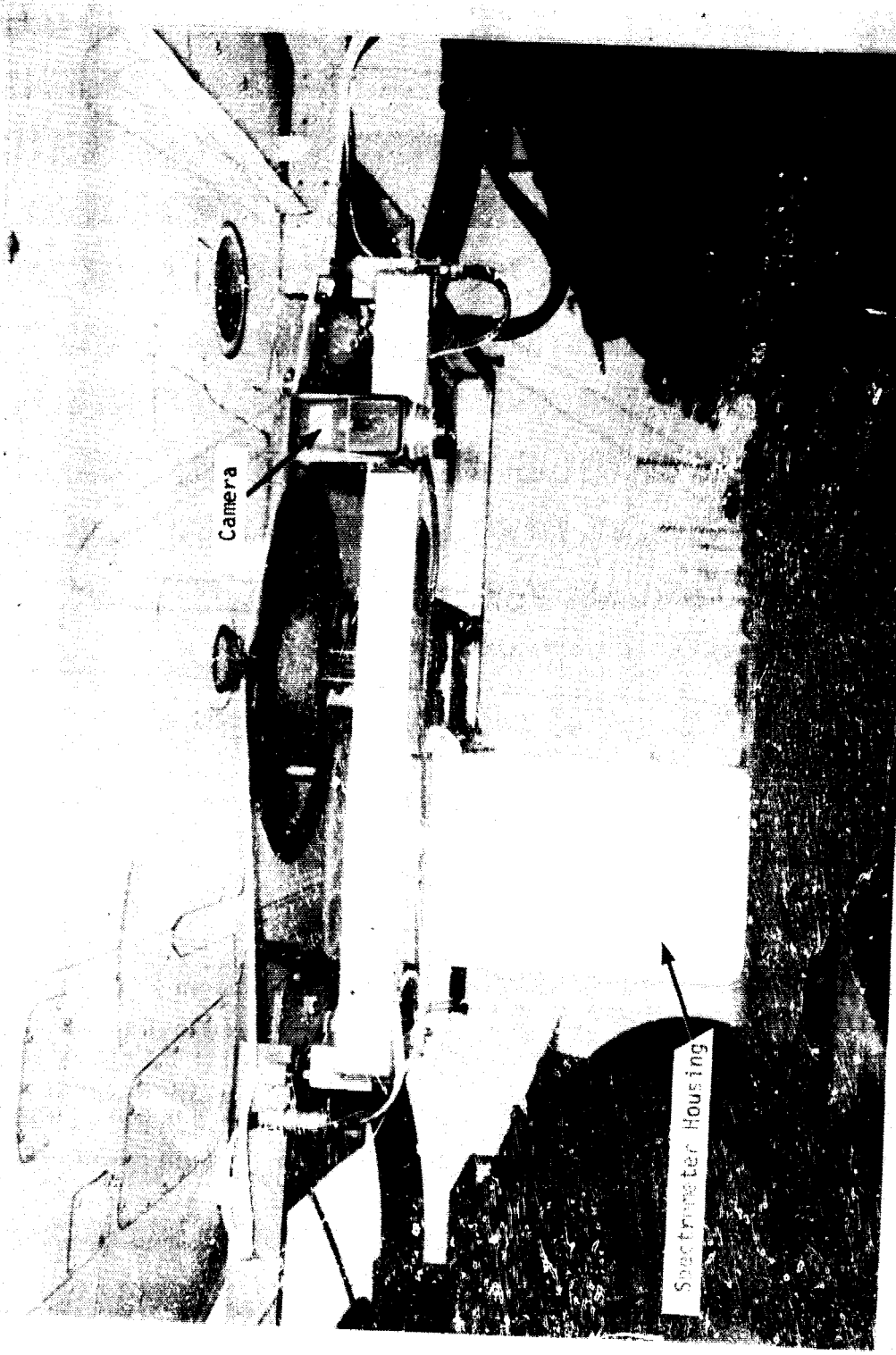
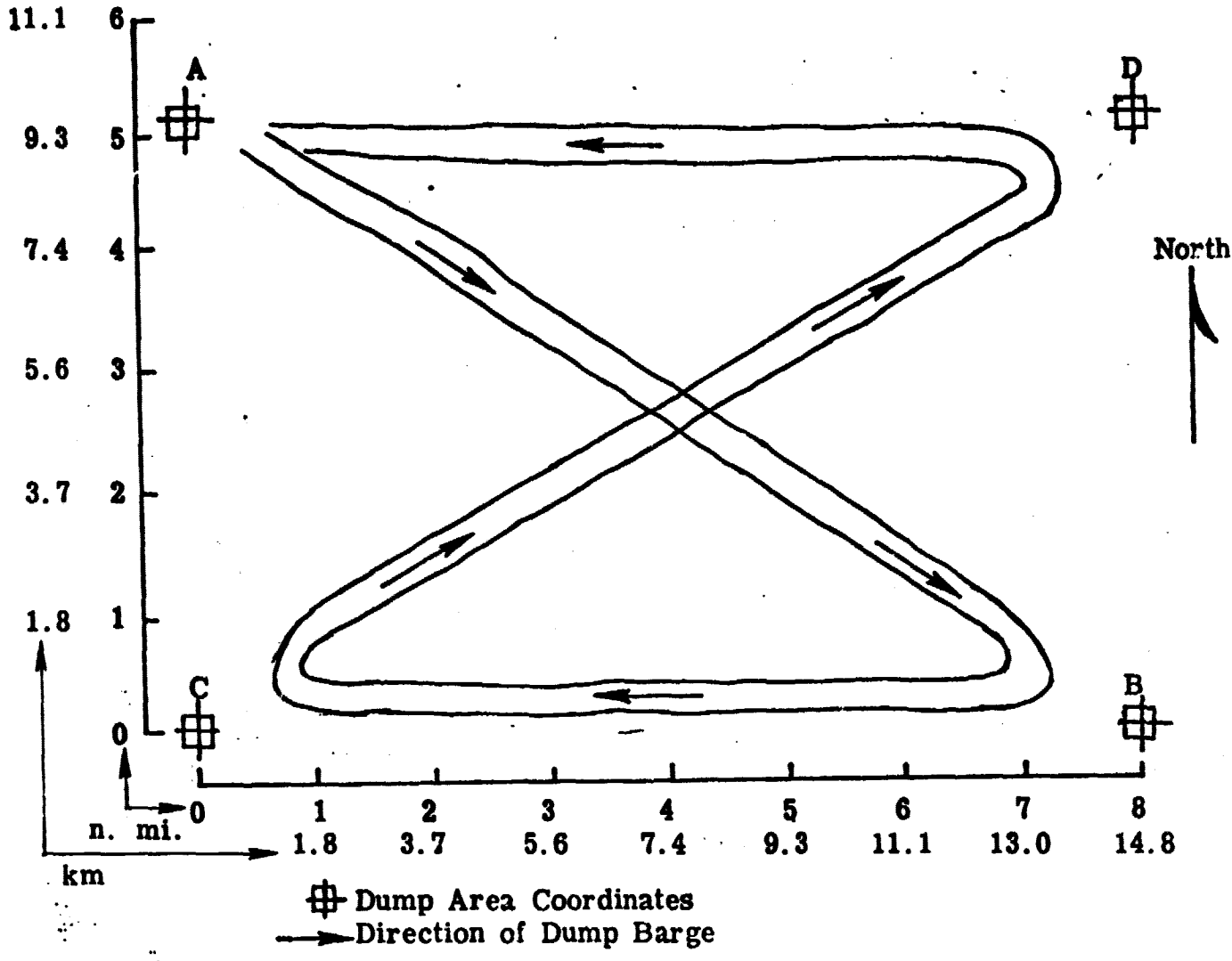
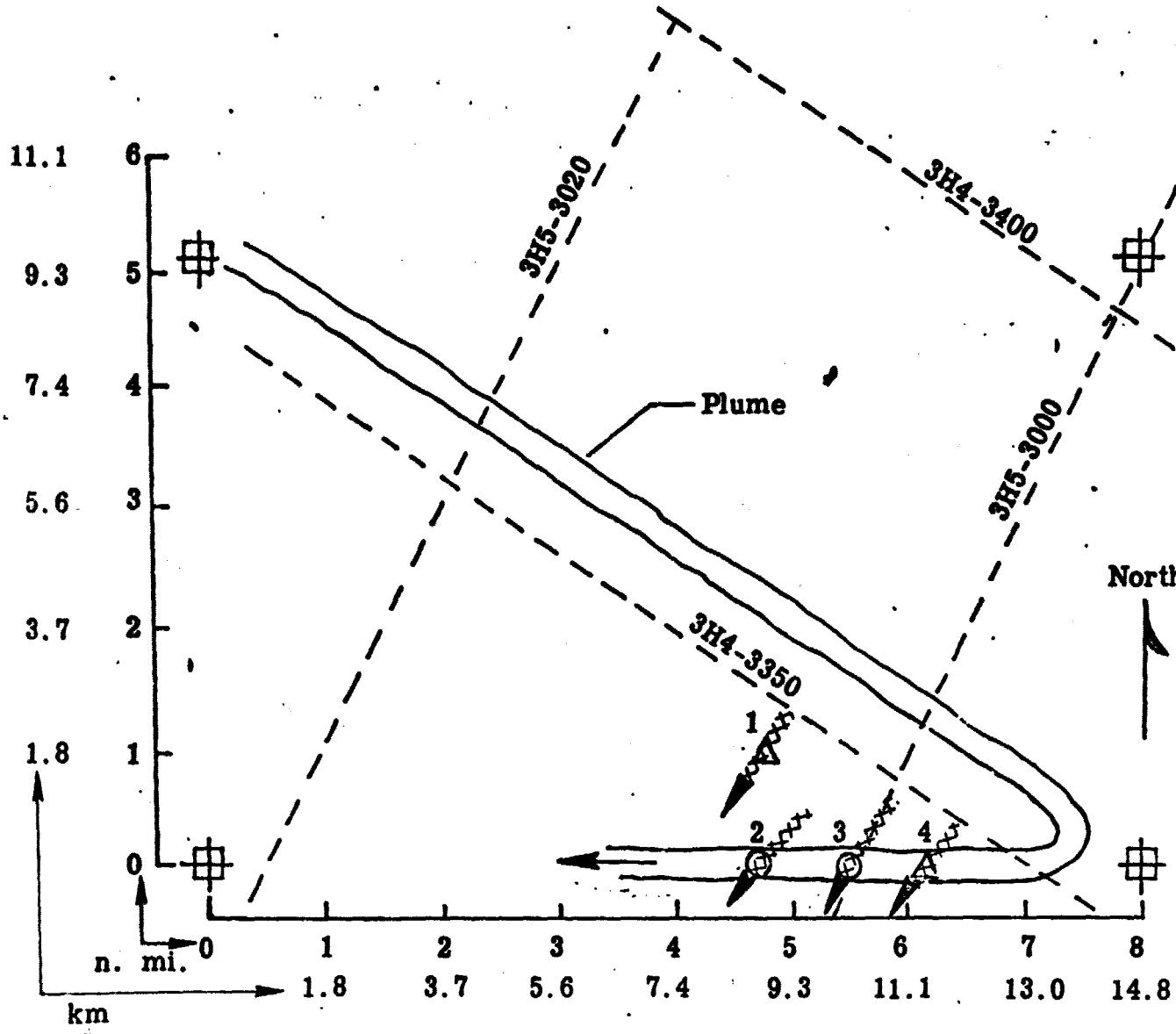


Figure 2.- Spectrometer attachment and Hasselblad camera.



Dump Barge Location	Time, EDT
Coordinate A. NW Corner. Begin Dump	0835 Recorded
Coordinate B. SE Corner	1025 Estimated
Coordinate C, SW Corner	1105 Estimated
Center Crossing	1213 Recorded
Coordinate D, NE Corner	1300 Estimated
Coordinate A, NW Corner, End Dump	1340 Recorded

Figure 3. - Barge Dump Pattern and Timing

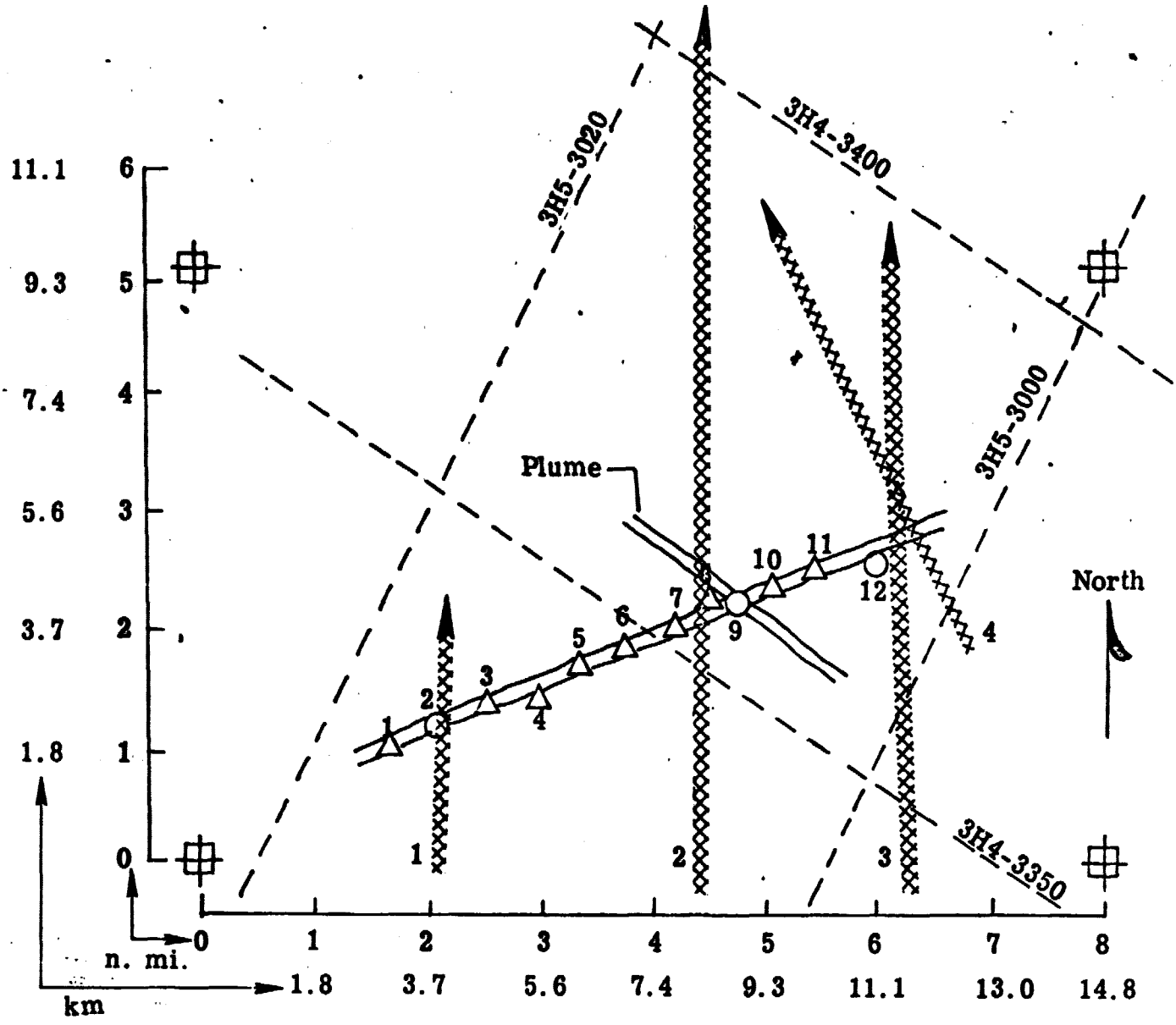


Station	Position
2	3H4-3335; 3H5-3005
3	3H4-3339; 3H5-3000

Flight Line	Heading, ^{o} True
All (See Table IX)	220^{o}

Dump Area Coordinates
Recorded Position
Estimated Position
LORAN A Grid
Flight Line

Figure 4. - Location of Data Stations and Flight Lines
Helicopter Morning Flight Period



Station	Position
2	3H4-3330; 3H5-3016
9	3H4-3357; 3H5-3008
12	3H4-3370; 3H5-3004

Flight Line	Heading, °True
1	352.8
2	0.2
3	356.1
4	336.7

Dump Area Coordinates
Recorded Position
Estimated Position
---LORAN A Grid
xxxxx Flight Line

Figure 5. - Location of Data Stations and Flight Lines
P3-A Morning Flight Period

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15. Supplementary Notes

16. Abstract

On October 7, 1976, a remote sensor experiment was conducted by the National Aeronautics and Space Administration and the University of Delaware. The experiment was conducted at a sewage sludge dump site off the Delaware/Maryland coast. Two aircraft serving as remote-sensor platforms flew over the dump site during a sludge dump. One aircraft carried a Bendix Multispectral Scanner (M^2S) and the other aircraft carried a Tektronix Rapid Scanning Spectrometer (RSS). Data from Sea-truth stations were collected concurrent with overpasses of the aircraft. All sensors were operational and produced good digital data.

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