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APPLICATION OF LANDSAT-2 TO THE MANAGEMENT OF DELAWARE'S MARINE AND WETLAND RESOURCES

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A. PROBLEMS

Funds in our account for purchasing LANDSAT imagery at NOAA/EDS/Satellite Data Services Branch have been exhausted. Since the size of our test site has been decreased, a small addition to the NOAA/EDS account would cover our data requests for the remainder of the contract.

B. ACCOMPLISHMENTS

1. General

Status of each objective is shown in terms of percentage of tasks completed.

Study Objectives	Status
1. Monitoring the dispersion and movement of ocean dump plumes. (Work Statement Tasks 1, 2, 3 and 4.)	65%
2. Suspended sediment concentration mapping. (Work Statement Tasks 5, 6 and 7.)	70%
3. Current circulation and density front charting for a model which predicts the drift and dispersion of oil slicks. (Work Statement Tasks 8, 9, 10 and 11.)	95%
4. Coastal land use and vegetation studies. (Work Statement Tasks 12, 13 and 14.)	95%
5. Comparison of training site and spectral signature (with atmospheric correction) techniques for classifying coastal land cover and environmental impact. (Work Statement Task 15.)	70%
6. Impact of Outer Continental Shelf development on the coastal zone of Delaware. (Work Statement Tasks 16, 17 and 18.)	50%

Most of the results attained were presented in progress reports, recent publications (Ref. 2 through 10), and LANDSAT follow-on evaluation reviews at NASA-Goddard Space Flight Center and NASA Langley Research Center (Ref. 11 and 12).

2. Dispersion and Drift of Ocean Dump Plumes

a.) Eighteen LANDSAT images of acid waste plumes at the duPont dump site 40 miles off the Delaware coast were used to obtain valuable data on plume drift and dispersion (Table 1). The deployment of radio-tracked current drogues at the same waste disposal site provided a cost-effective means of tracking water mass movement from the surface down to near-bottom depths.

b.) The maximum range of measurable wastes estimated by previous investigators as being about ten nautical miles from the discharge point was substantiated by the satellite imagery (Figure 1).

c.) The average drift velocity of surface drogues and the waste plumes as observed by LANDSAT was about 0.5 knot. Mid-depth and near-bottom drogues released at the dump site moved at average speeds of about 0.46 and 0.36 knot respectively. Drogues released at different depths frequently traveled along different paths and at different speeds, indicating the presence of current shear. The circulation processes at the waste dump site are highly storm dominated with an increase of water transport occurring during storms.

d.) During the stratified warm months, more drogues tended to move in the north-northeast direction, while during the non-stratified winter months a southwest direction was preferred. The predominant direction of movement of the waste plumes imaged by the LANDSAT satellite was to the southwest.

e.) A distinct summer thermocline was observed from June through August at depths ranging from 43 to 103 feet. During the remainder of the year, the ocean at the test site was not stratified, permitting wastes to mix throughout the water column to the bottom (Figure 2).

Table 1.

Waste Plume Characteristics Derived from LANDSAT Imagery

	Date	Hours After Dump	Lateral Extent (N.M.)	(N to S) Axis Orientation	Distance Between Centroids (N.M.)	Axis Orientation	Maximum Distance from Center of Dump Site (N.M.)	Axis Orientation
1)	10/10/72	(9h30)	10	155°	8.5	250°	10	285°
2)	10/27/72	(14h08)	5	260°	4	225°	5	225°
3)	1/25/73	(4h03)	5	120°	4.5	275°	8	285°
4)	4/07/73	(4h03)	8	110°	3	280°	5	295°
5)	5/13/73	(during)	1	105°	3	260°	3.5	260°
6)	10/22/73	(29h25)	14.5	225°	12	195°	15	205°
7)	10/23/73	(53h31)	14	200°	24.5	215°	27	210°
8)	4/20/74	(14h47)	7	145°	7	215°	8.5	185°
9)	5/26/74	(21h06)	7.5	145°	10.5	235°	13	235°
10)	11/04/74	(46h26)	7	240°	3.5	120°	6.5	90°
11)	8/19/75	(during)	7.5	120°	1.5	160°	4	13°
12)	8/28/75	(just after)	6	220°	1.5	270°	5.5	245°
13)	10/21/75	(6h35)	8	250°	3.5	185°	6	235°
14)	11/17/75	(8h16)	8	120°	2	160°	5	160°
15)	1/19/76	(6h10)	6.5	245°	2	245°	4.5	240°
16)	2/24/76	(9h10)	10	105°	4	135°	8	115°
	AVERAGE		7.8	175.9°	5.3	206.4°	8.8	212.5°

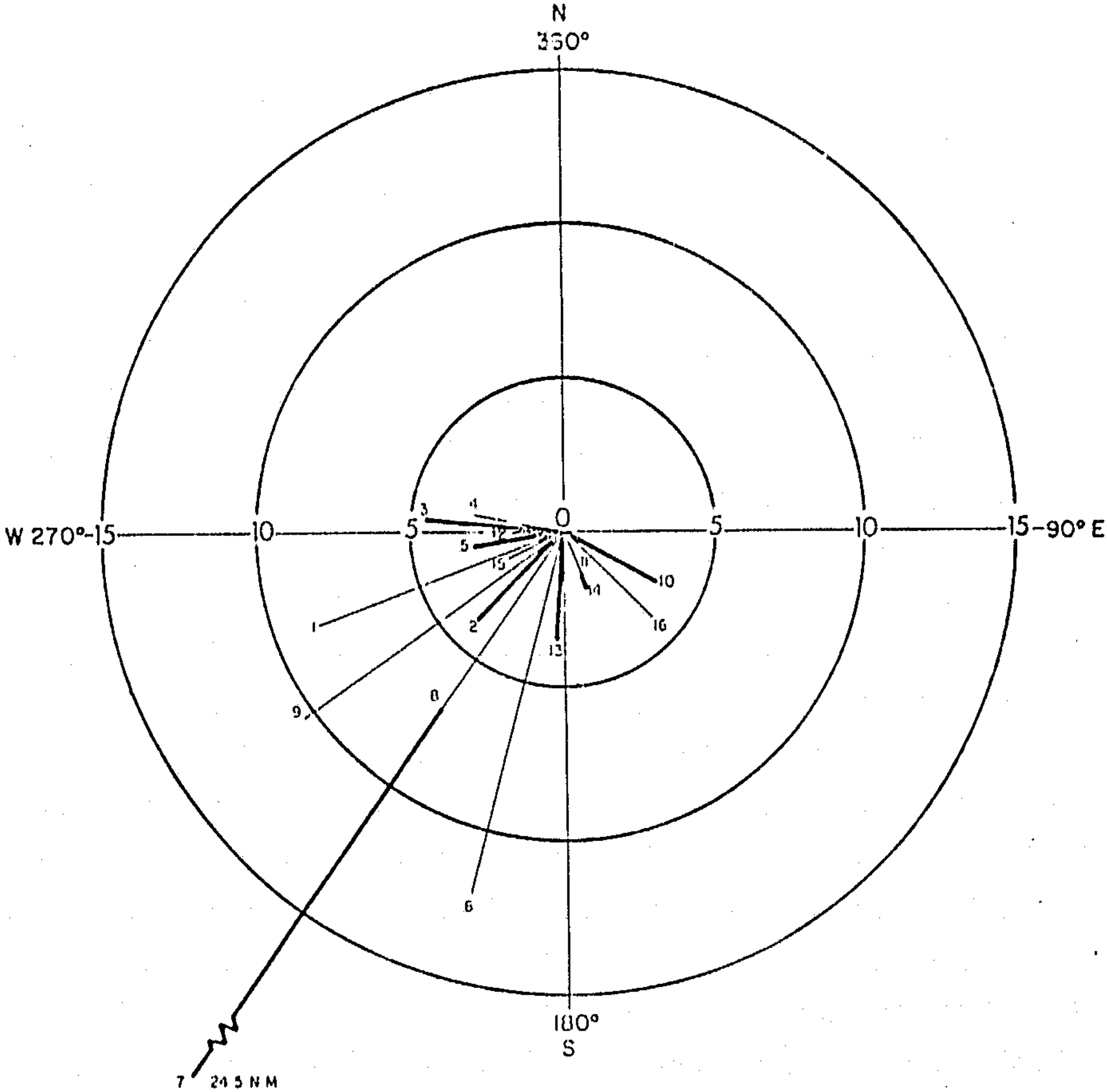

Figure 1. Distance from center of dump site to estimated centroid of imaged plume.

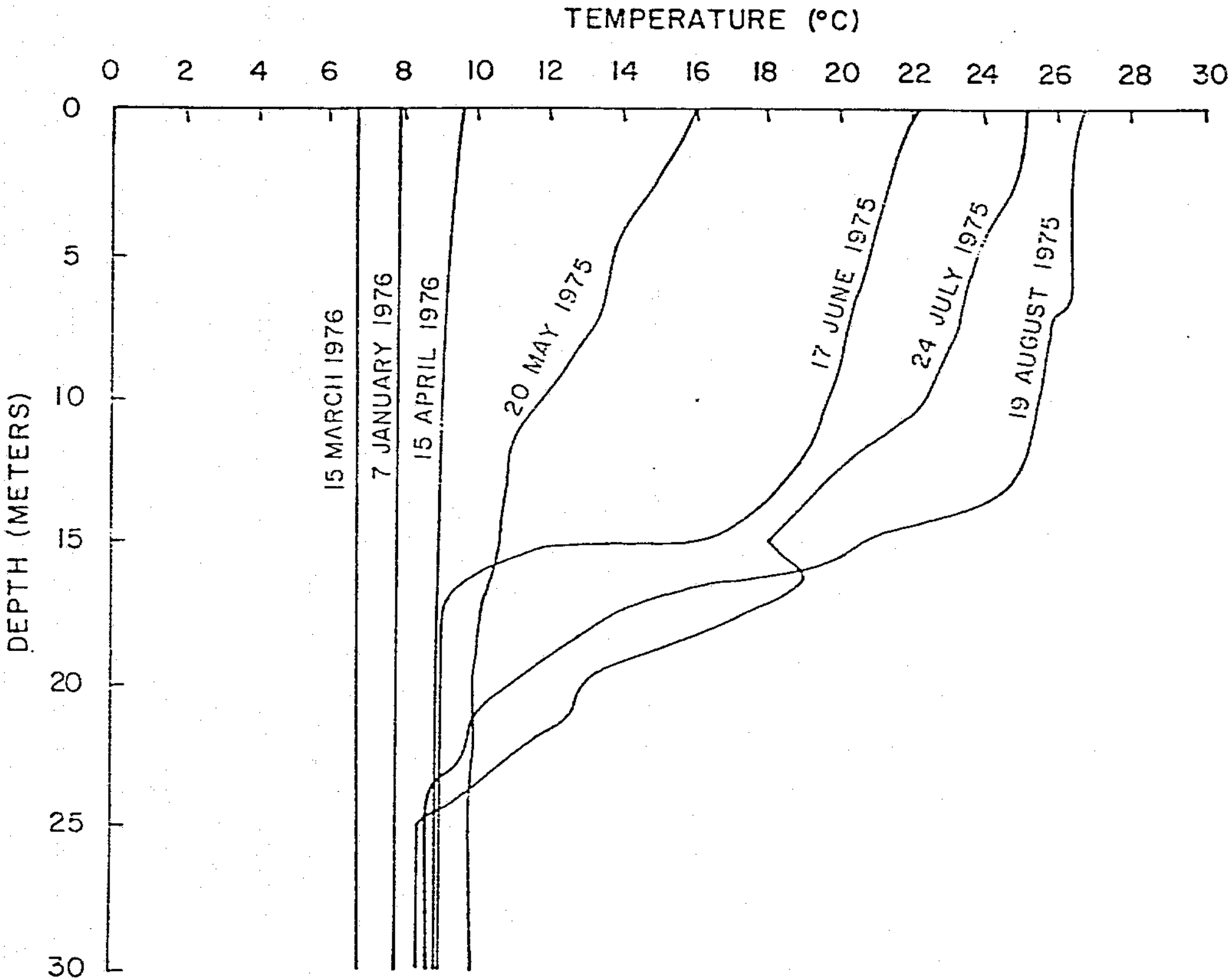

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Figure 2.
Temperature profiles obtained with an Expendable Bathythermograph show water stratification and thermocline location during summer months.

3. Oil Slick Movement Model Verification

a.) LANDSAT and aircraft supported by ships were used successfully to study the effects of density fronts on oil slick movement and dispersion.

b.) Coastal and estuarine density fronts were found to concentrate oil slicks, change their shape, modify their dispersion and change their direction of movement.

c.) Thirty-six LANDSAT images were used to determine the location, type and extent of density fronts under different tidal conditions. This data was used to modify an oil drift and spreading model to include the effects of fronts (Figures 3, 4 and 5).

d.) As predicted by preliminary modeling work, most of the density fronts formed on the New Jersey side during flood tide and on the Delaware side of the Bay during ebb tide.

e.) Clean-up operations depending on real-time use of oil slick movement prediction models will benefit not only from aircraft tracking the actual slicks but also from real-time satellite observations of surface currents and the location of frontal systems.

C. SIGNIFICANT RESULTS

Coastal Land Use and Vegetation Studies

a.) Digital multispectral classification techniques can be used to discriminate coastal land use and vegetation with 87% to 94% categorization accuracy.

b.) Wetlands plant species, representing more detail than U.S.G.S. classification system Level II categories can be discriminated using LANDSAT data with 85% to 88% accuracy at scales up to 1:24,000.

Figure 3.

Boundaries visible in Landsat images of Delaware Bay taken one hour before maximum ebb at the entrance of the bay.

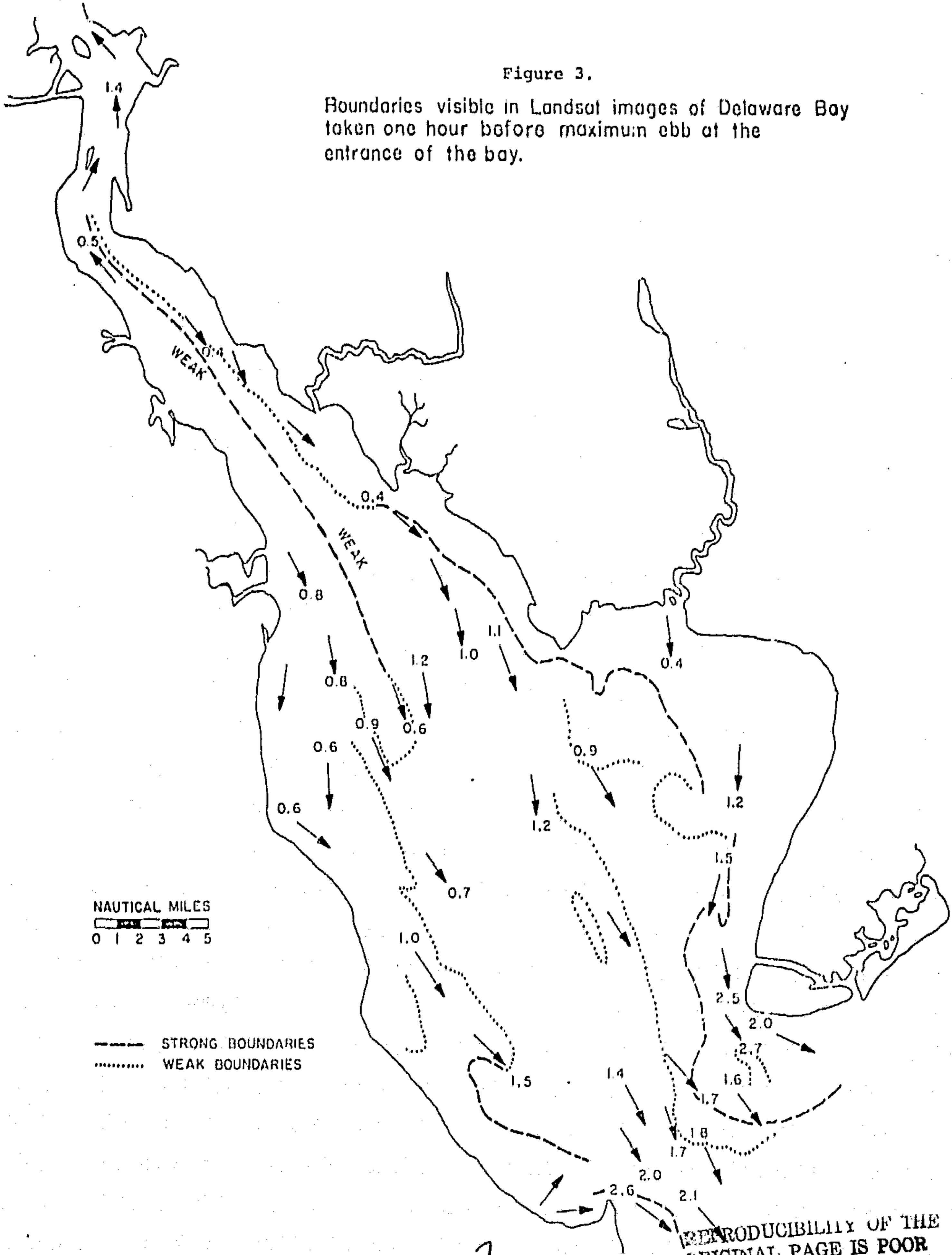

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Figure 4.

Boundaries visible in Landsat images of Delaware Bay taken at maximum ebb at the entrance of the bay.

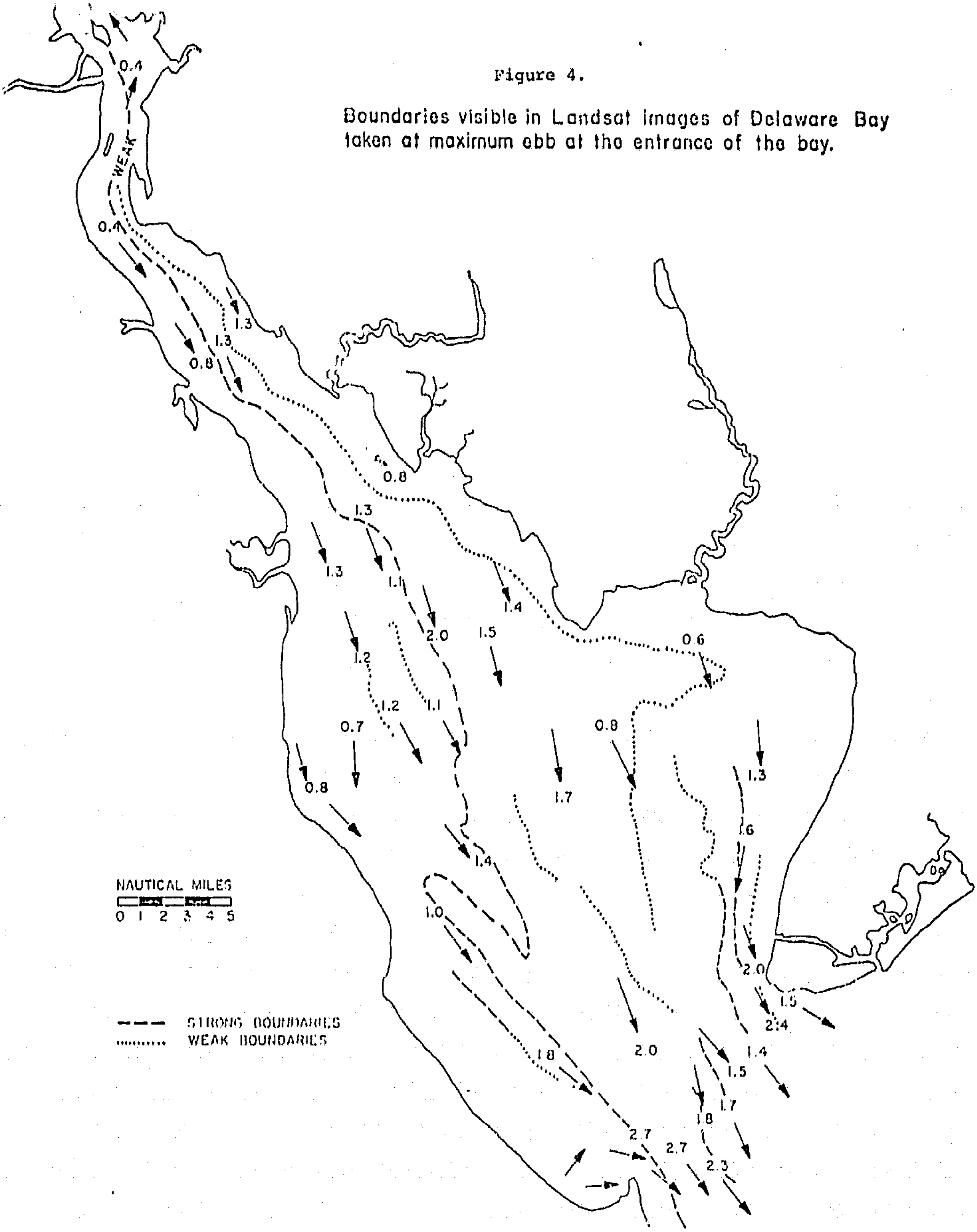
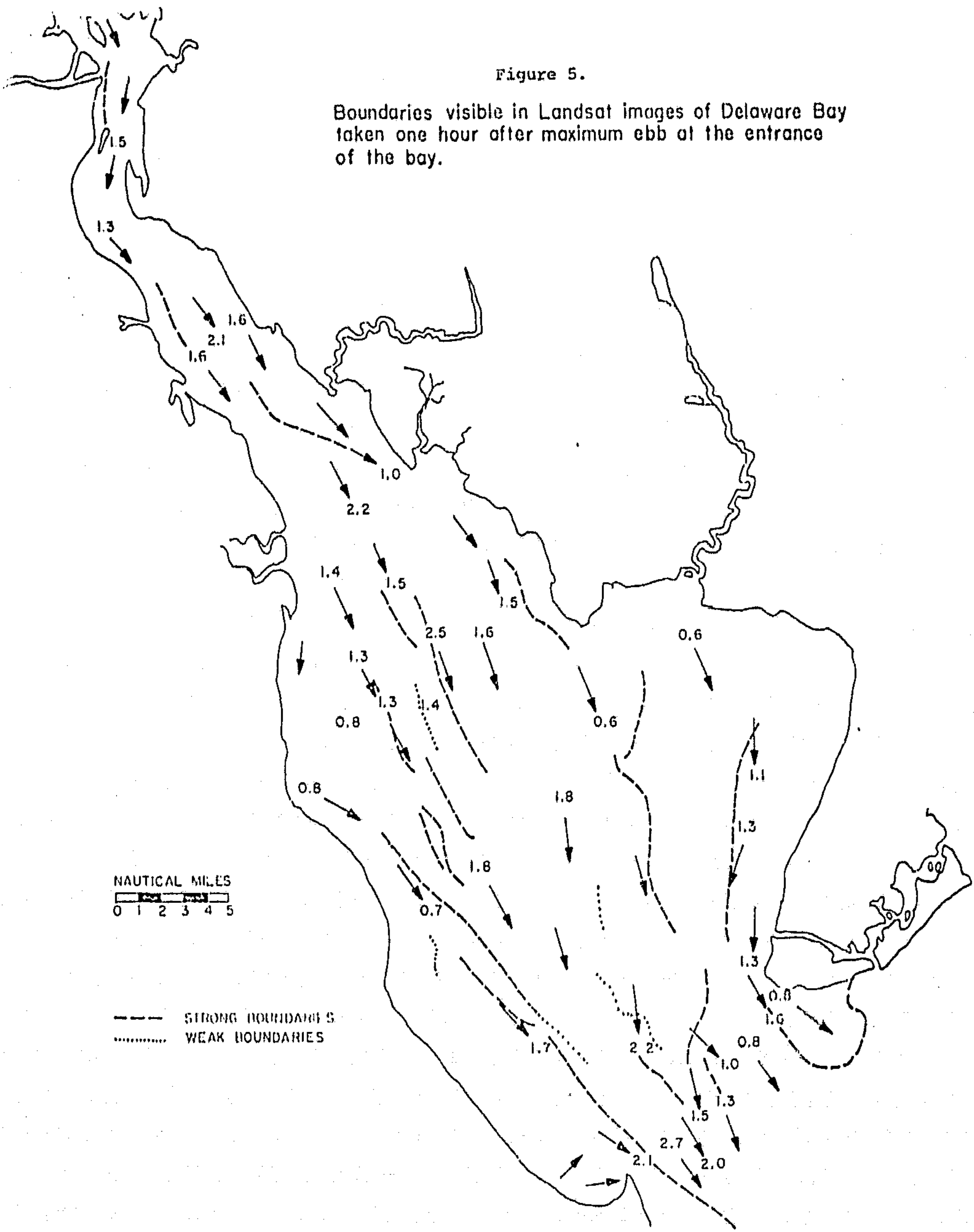


Figure 5.

Boundaries visible in Landsat images of Delaware Bay taken one hour after maximum ebb at the entrance of the bay.



c.) Atmospheric measurement and correction techniques allow ground-measured absolute reflectance to be used for training of multi-spectral analysis without degrading classification accuracies achieved with conventional relative radiance training data.

d.) *In situ* reflectance measurement is a more effective way of generating target signatures when large homogeneous expanses of the target cover type are not present and when variability of reflectance can be used to make detailed inferences about the type of interest.

e.) Radiance measurements made by investigators on the ground or by the LANDSAT-MSS, when transformed to "absolute reflectance" through application of atmospheric corrections, may be manipulated and extended independently of the solar and atmospheric conditions present at the time of data collection. Appropriate training data may be applied to analysis of any data for which atmospheric correction has been applied. In detection of change over time such extension of signatures is critical.

D. PUBLICATIONS

1. Klemas, V., Invited presentation to Captain Jacques Cousteau and Dr. Philippe Cousteau on Ocean Current Measurement with Integrated Drogue-Aircraft-Satellite Syste,s NASA Headquarters, Washington, D.C., October 6, 1975.

2. Klemas, V., Bartlett, D., Rogers, R., Coastal Zone Classification from Satellite Imagery. Photogrammetric Engineering and Remote Sensing, Journal of the American Society of Photogrammetry, Vol. 41, No. 3, April, 1975.

3. Klemas, V., Otley, M., Wethe, C., Rogers, R., ERTS-1 Studies of Coastal Water Turbidity and Current Circulation, American Geophysical Union 55th Annual Meeting, Washington, D.C., April 8-12, 1974.

4. Klemas, V., Tornatore, G., Whelan, W., A New Current Drogue for Monitoring Shelf Circulation, American Geophysical Union 56th Annual Meeting, Washington, D.C., June 16-20, 1975.

5. Klemas, V. and Bartlett, D., Application of ERTS-1 and Skylab to Coastal Zone Management, NASA Earth Resources Survey Symposium, Houston, June 8-13, 1975.

6. Klemas, V., Davis, G., Wang, H., Whelan, W., Tornatore, G., A Cost-Effective Satellite-Aircraft-Drogue Approach for Studying Estuarine Circulation and Shelf Waste Dispersion, Proceedings Ocean 75 Conference, San Diego, 1974.

7. Klemas, V., Davis, G., Wang, H., Whelan, W., Monitoring Estuarine Circulation and Ocean Waste Dispersion Using Integrated Satellite-Aircraft-Drogue Approach, International Conference on Environmental Sensing and Assessment, Las Vegas, September 14-19, 1975.

8. Klemas, V., Remote Sensing of Wetlands Vegetation and Estuarine Water Properties, Proceedings Third International Estuarine Research Conference, Galveston, October 6-9, 1975. (Invited paper.)

9. Eight reports on significant results to NTIS.

10. Klemas, V. and Polis, D. F., Remote Sensing of Estuarine Fronts and their Effects on Oil Slicks, University of Delaware Publication CMS-RANN-4-76, 48 pp., 1976.

11. LANDSAT follow-on investigation interviews conducted at NASA Goddard Space Flight Center, Greenbelt, Md. on October 18, 1976.

12. Review of Basic Research in NASA-related Environmental Quality Monitoring held at NASA Langley Research Center, Hampton, Va. on December 8, 1976.

E. RECOMMENDATIONS

Order NOAA/EDS not to send LANDSAT-2 prints and transparencies with excessive cloud cover. Also action has been taken to decrease the size of our test site in order to conserve funding in our imagery accounts. Add more money to NOAA/EDS account.

F. FUNDS

On schedule for Objectives 1, 2, 3 and 4. Insufficient for Objectives 5 and 6.

G. DATA USE

All ordered LANDSAT-2 tapes have been received so far. They have been evaluated and are currently being analyzed.

H. AIRCRAFT DATA

Aircraft overflights have been on time and on target. Most of the imagery has been received and more imagery is on order.

I. PERSONNEL CHANGES

None