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Paper M 3

APPLICABILITY OF ERTS-1 IMAGERY TO THE STUDY OF SUSPENDED SEDIMENT AND AQUATIC FRONTS

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Imagery from three successful ERTS-1 passes over the Delaware Bay and Atlantic Coastal Region have been evaluated to determine visibility of aquatic features. Data gathered from ground truth teams before and during the overflights, in conjunction with aerial photographs taken at various altitudes, were used to interpret the imagery. The overpasses took place on August 16, October 10, 1972, and January 26, 1973, with cloud cover ranging from about zero to twenty percent. (I.D. Nos. 1024-15073, 1079-15133, and 1187-15140). Visual inspection, density slicing and multispectral analysis of the imagery revealed strong suspended sediment patterns and several distinct types of aquatic interfaces or frontal systems.

The interfaces are a major hydrographic feature in Delaware Bay and frequently include regions of high convergence. As shown in Figure 1, in the upper and middle bay and interfaces tend to align along the flow axis of the river or parallel to the shoreline. They are strongest during the ebb portion of the tidal cycle and seem to be associated with velocity shears induced by differences in bottom topography. Boundaries like the one shown in Figure 2 exhibit a strong change in color and turbidity, with Secci depths changing by roughly a factor of two as one crosses them. Convergence of these boundaries is illustrated in Figure 3, which shows a boundary moving across the anchored fluorescein dye pack, and capturing and holding the end of the dye streak. The displacement of portions of the wake of a ship crossing a boundary, shown in Figure 4, is an indication of shear along the boundary. Storms tend to break up the boundaries, with three dimensional patches of the more turbid water not mixing with the less turbid water, but clinging together up to one hour after the boundary itself has been destroyed.

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EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

The second type of interface, shown in Figure 5, is primarily a tidal intrusion of the shelf water during incipient flood tide, with associated discontinuities in salinity and temperature. The convergence properties of such fronts attract heavy accumulations of foam which were found to contain strong concentrations of toxic substances. The shelf water, having higher salinity and density than bay water, tends to penetrate into the bay along the deep channel, and thus establish higher salinity in the middle than near the shores of the bay. (Figure 6). Thus the apex of the frontal wedge in Figure 5 is moving along the deep channel of the bay.

Figure 7 shows ERTS-1 imagery of the mouth of Delaware Bay in band 5 obtained on August 16, 1972. Best visibility of boundaries and sediment plumes was obtained in band 5. As illustrated in Figure 8, locally suspended sediment is visible above the shoals near Cape May. One boundary is visible near the middle of the bay mouth, a second one protrudes in the southerly direction from Cape Henlopen, and a third one extends in the southeasterly direction further south, near Indian River Inlet. This boundary was moving rapidly at the time and divers operating in 18 feet of depth noted a change in visibility from two feet to six feet as the boundary passed over the tower they were working on. Figure 9 shows the boundary approaching the beach two miles north of Indian River Inlet. Figure 10 shows a similar boundary moving shoreward, as seen from an aircraft. The tide condition at the time of the ERTS-1 pass was near peak flood velocity at the mouth of the bay. Since microdensitometry traces between the Capes in Figure 7, seem to correlate with the depth profile, most of the visible suspended sediment should represent sand from local shoals and shallow areas put into temporary suspension by the flood current and waves. Sample analyses and Secci depth measurements seem to support this conclusion. This relationship becomes more complex during ebb tide when large quantities of silt and clay are also present.

Figures 11 and 12 show band 5 imagery from ERTS-1 passes over Delaware Bay on October 10th, 1972, and January 26th, 1973 respectively. Figures 13 and 14 describe the tidal conditions in the bay at the time of the respective ERTS-1 overpasses. Note that on October 10th there was high water slack at the baymouth and peak flood near the Chesapeake and Delaware Canal, in the upper portion of the bay. (Figure 13). Therefore, as illustrated in Figure 15, very strong boundaries are visible in Figure 11 in the upper portion of the bay. In contrast, according to Figure 14, on January 26th, the baymouth was flooding; near the C & D Canal the tide was ebbing; and there was a high slack in the upper half of the bay. Therefore the ERTS-1 image in Figure 12 shows considerable mixing and less boundary formation in the upper portion of the bay than the image in Figure 11.

The three transsects across the bay shown in Figure 15 are traversed by boats and low altitude aircraft during ERTS-1 overpasses to collect ground truth. Boats and aircraft were coordinated via radio, to direct the ground teams to stations. At each station, water samples were taken at the surface and/or one meter depth. Secchi depth, temperature, color and salinity were also recorded. The water samples were filtered using a Millipore filtration apparatus and 54mm Gilman glass filter pads. The filter pads were dried at 105°C, dessicated and weighed to determine the mass of the particulate matter. Carbon analyses were run on filter pads from each station to determine total percent carbon, by weight. X-ray diffraction analyses are presently being conducted on the remaining filter pads, to determine clay mineralogy. Densitometer traces and density slicing across all ERTS-1 bands are currently being correlated with suspended sediment load, sediment size, Secci depth and other parameters. (Figure 16).

Before the October 27, 1972, pass of ERTS-1, an 800 foot wide slick of Rhodamine-B dye was inserted at the proposed eight mile site for an offshore oil terminal, as shown in Figure 17. Cloud cover prevented the satellite from imaging the dye slick, however, aircraft tracking the dye patch recorded a boundary sweep across the dye patch stretch it along the boundary, and carry it about a mile towards the bay during flood tide. The stretched dye slick is shown in Figure 18, at the end of its one mile traversal, using narrowband red filters to enhance the weakened dye concentration. Coordinated experiments involving dye drops, sludge and acid disposal during ERTS-1 overpasses will be carried out during the coming six weeks.

ERTS-1 Multispectral scanner band 5 (0.6-0.7 microns) gave the sharpest definition of interfaces between waters of differing turbidity. Band 4 (0.5-0.6 microns), due to its deeper water penetration, was more sensitive to patterns having lower turbidity, yet was veiled by a uniform blanket of atmospheric scattering making identification of sediment patterns more difficult. Band 6 (0.7-0.8 microns) and band 7 (0.8-1.1 microns) clearly delineated the shore line and discriminated water from land in the marshes.

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Figure 1: Aquatic interfaces and frontal systems observed in Delaware Bay.

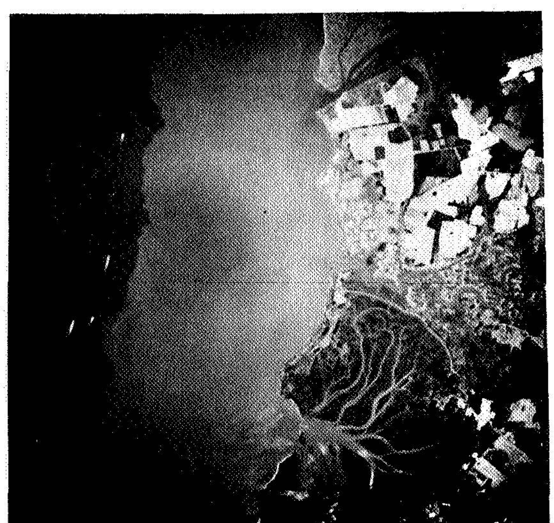

Figure 2: A shear boundary near the Delaware Coast.

Figure 3: Dye experiment to show convergence properties of boundary.

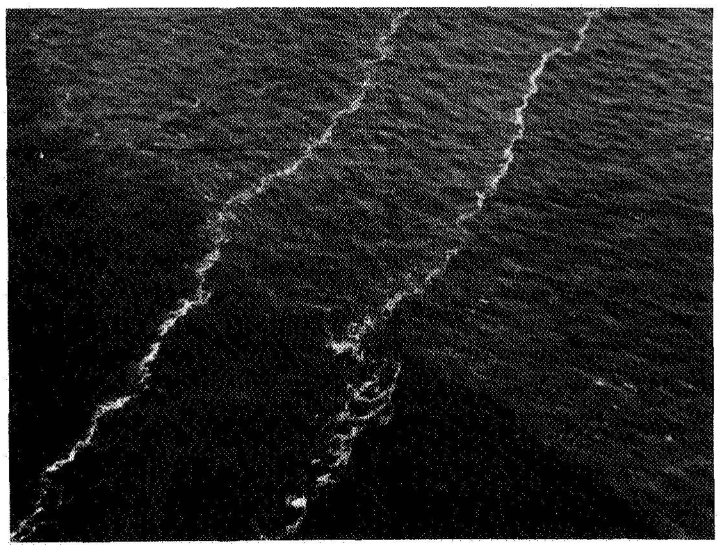

Figure 4: Shear visible in displacement of wake of ship crossing boundary.

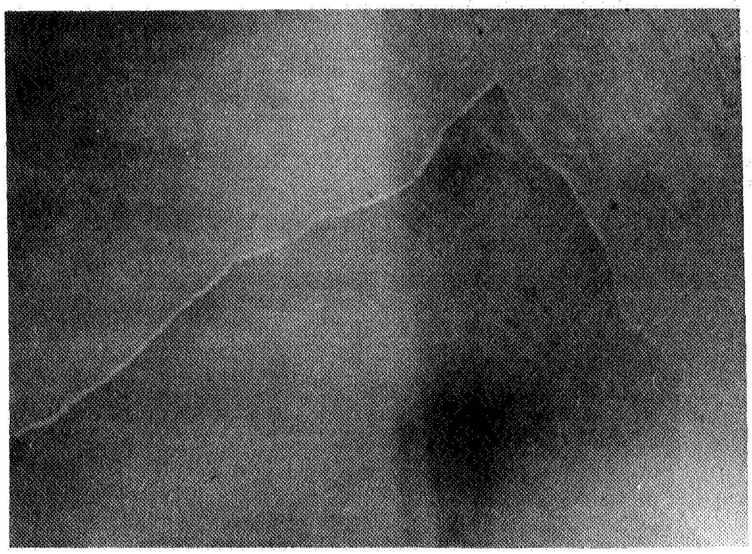

Figure 5: Frontal system due to salt water intrusion into Delaware Bay.

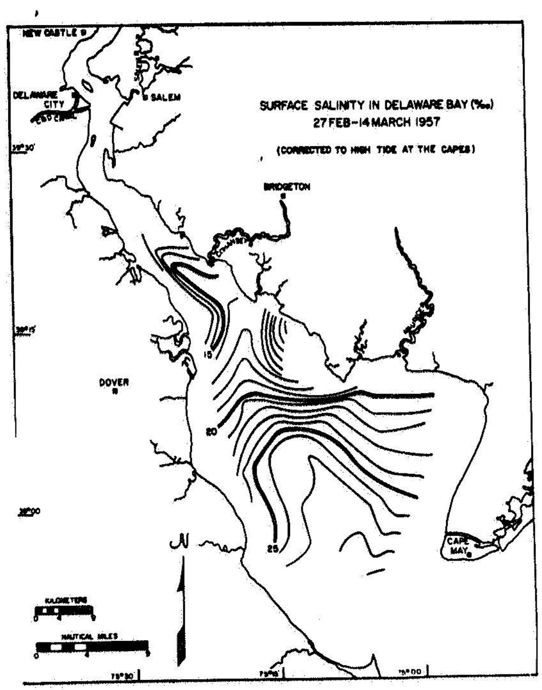

Figure 6: Salinity distribution in Delaware Bay.

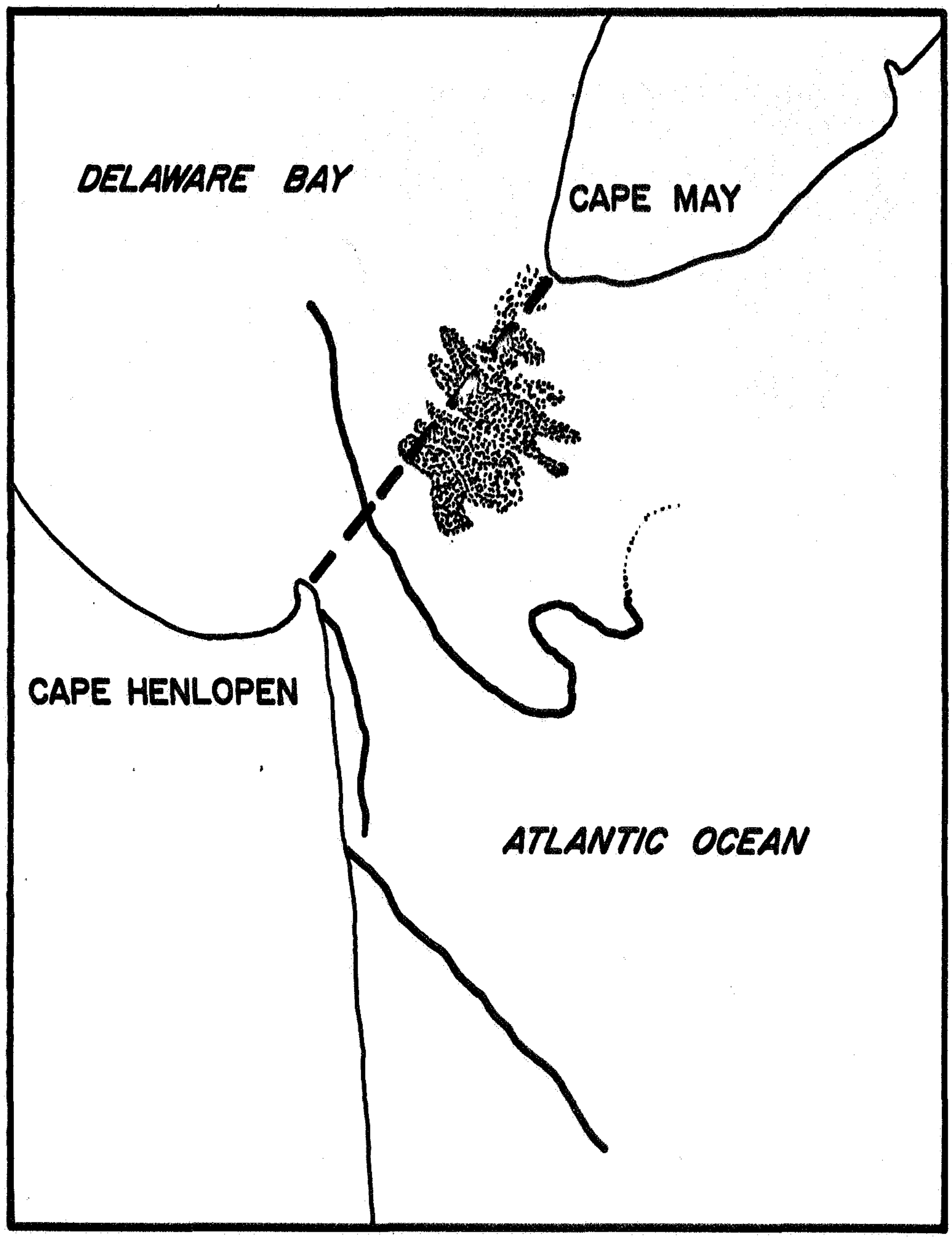

Figure 7: Aquatic boundaries and suspended sediment plumes identified in the ERTS-1 image of August 16, 1972, shown in Figure 6.

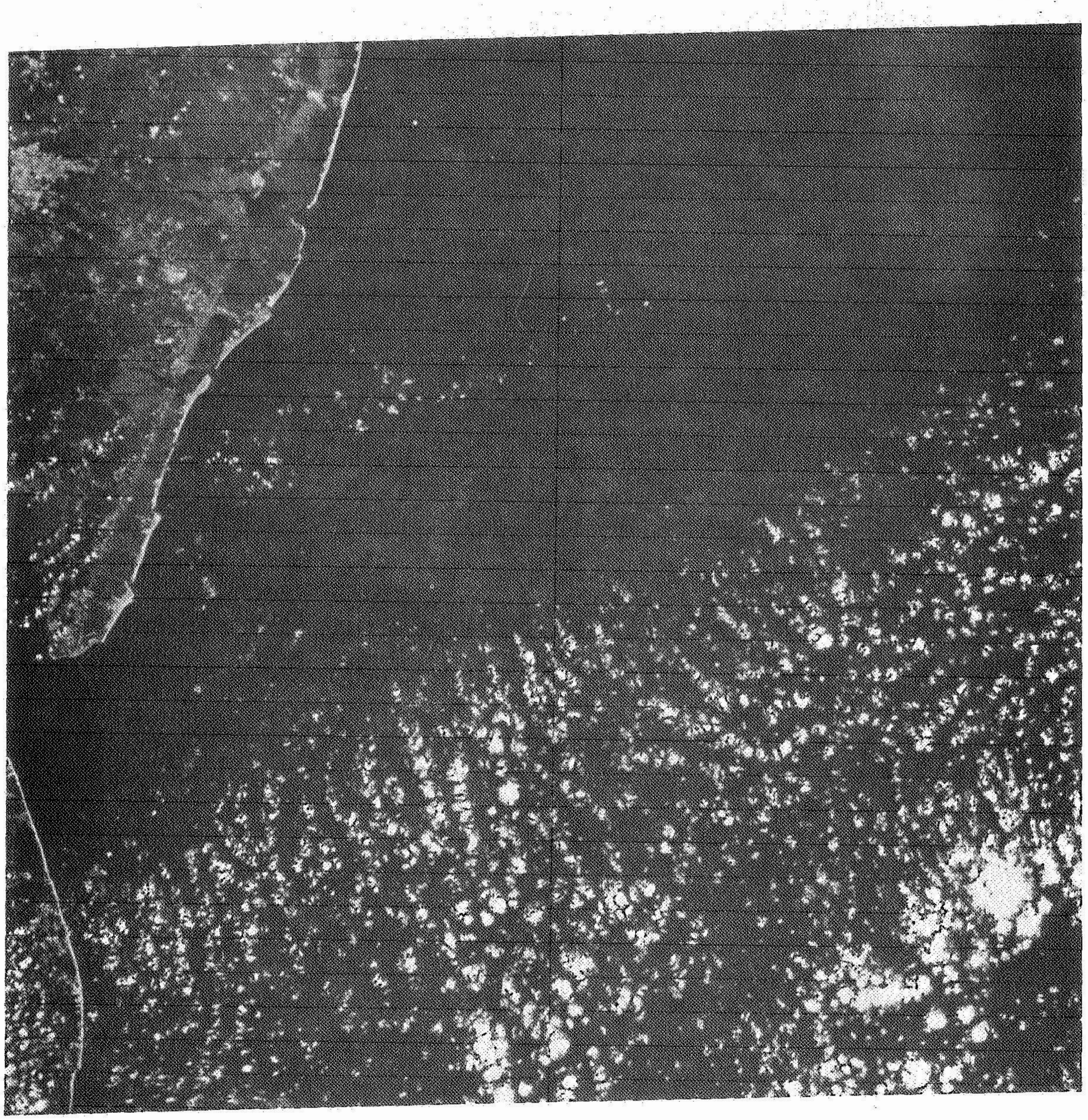

Figure 8: ERTS-1 image of the mouth of Delaware Bay
(Band 5, August 16, 1972, I.D. 1024-15073).

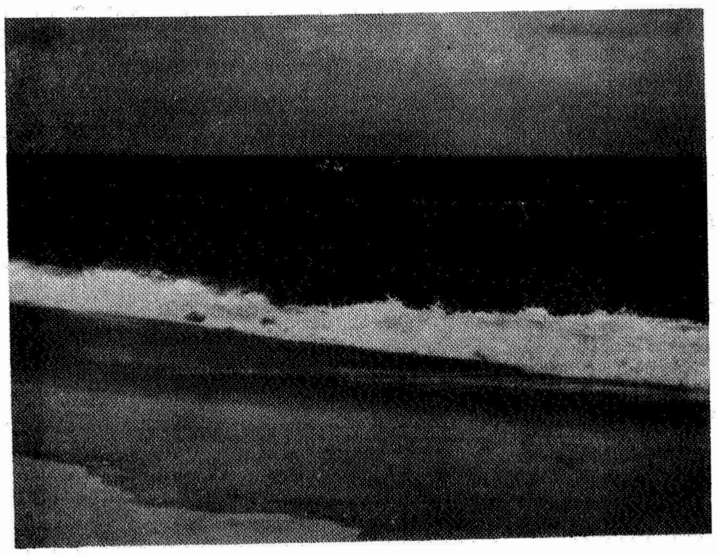

Figure 9: Boundary in ERTS-1 picture of Figure 7 seen approaching the beach.

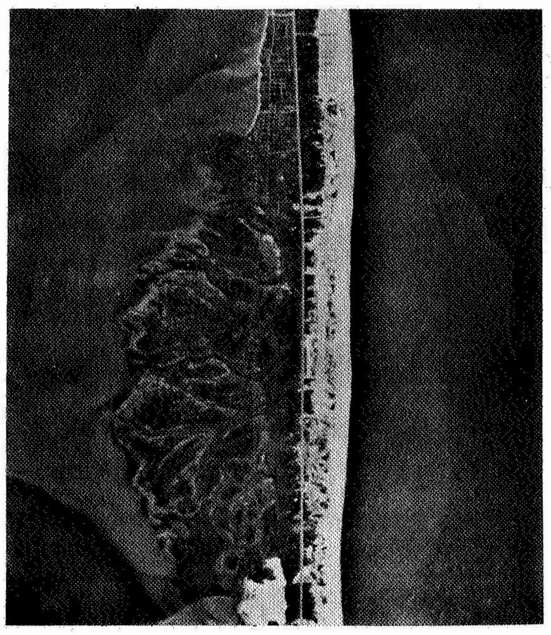

Figure 10: Aircraft picture of boundary near Indian River Inlet.

Figure 11: ERTS-1 image of Delaware Bay obtained in band 5 on October 10, 1972. (I.D. No. 1079-15133).

Figure 12: ERTS-1 image of Delaware Bay obtained in band 5 on January 26, 1973. (I.D. No. 1187-15140).

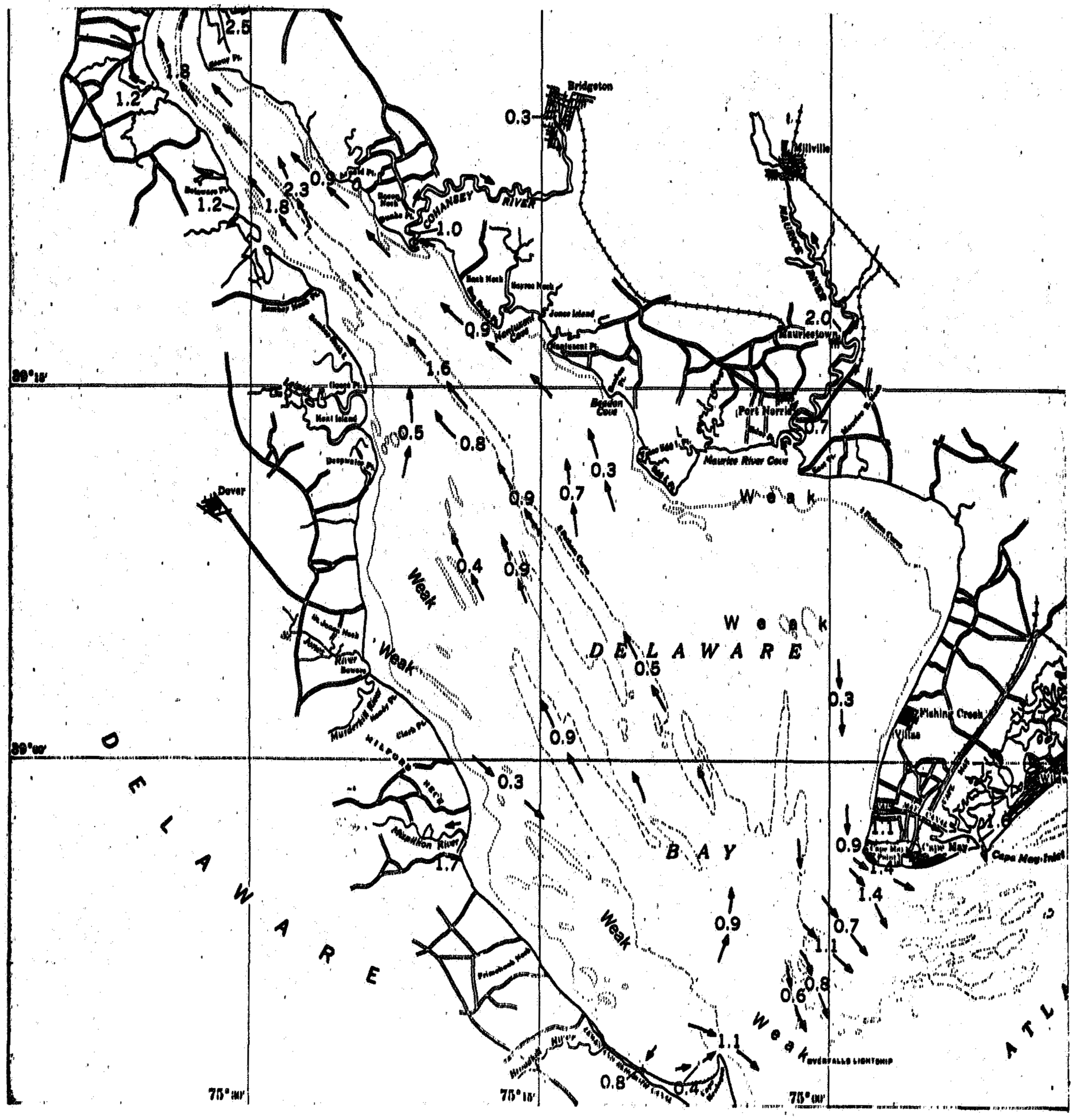

Figure 13 **Tidal conditions in Delaware Bay at the time of the ERTS-1 image shown in Figure 11. The upper bay is near maximum flood, resulting in sharp shear boundaries.**

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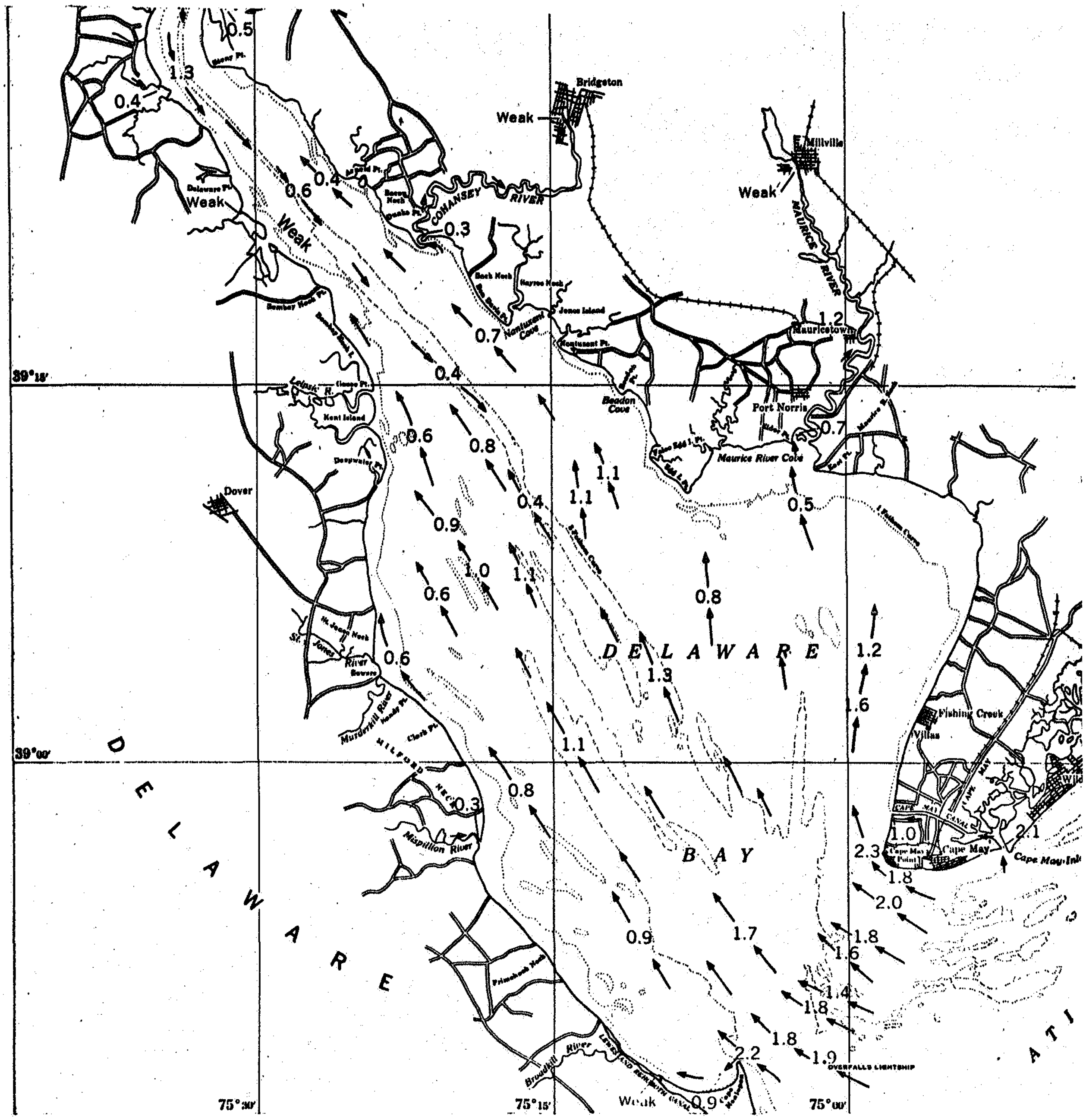

ONE HOUR BEFORE MAXIMUM FLOOD AT DELAWARE BAY ENTRANCE

Figure 14 Tidal conditions in Delaware Bay at the time of the ERTS-1 image shown in Figure 12. The upper bay is near high water slack, causing boundaries to weaken and more mixing to occur.

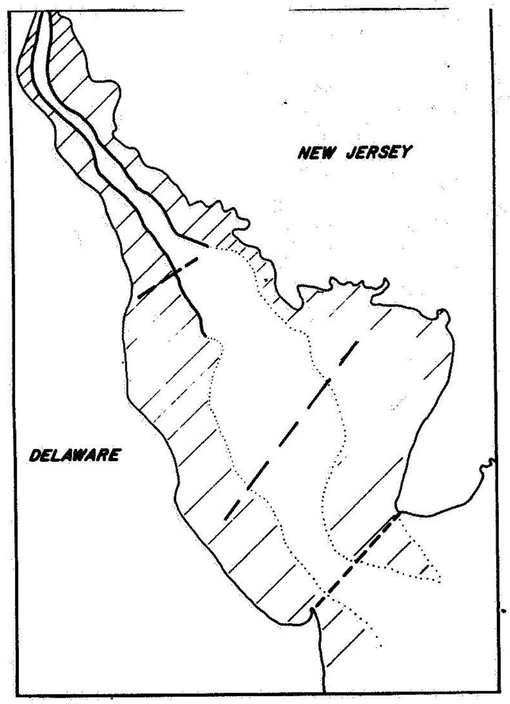

Figure 15: Aquatic boundaries and suspended sediment visible in ERTS-1 image of October 10, 1972, shown in Figure 11. Transsects of boats and aircraft collecting ground truth are shown in the upper, middle and lower Delaware Bay.

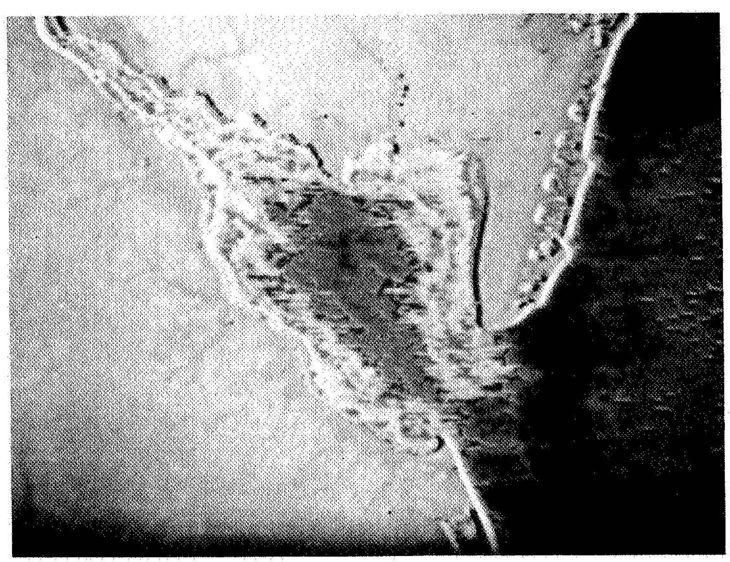

Figure 16: Result of Color Density Slicing of ERTS-1 Image of Figure 11. (October 10, 1972, pass over Delaware baymouth).

Figure 17: Rhodamine-B dye patch injected at proposed 8-mile off-shore oil terminal site. The size of the patch is about 800 feet.

Figure 18: Dye patch is captured by moving frontal systems and carried one mile towards the Bay.