N73-28388

DETECTION OF TURBIDITY DYNAMICS IN TAMPA BAY, FLORIDA USING MULTISPECTRAL IMAGERY FROM ERTS-1

A. E. Coker, Aaron Higer and Carl R. Goodwin[1]

ABSTRACT

In 1970, Congress authorized the deepening of the Tampa Bay channel (Rivers and Harbors Act of 1970) from 34 to 44 feet. In order to determine the effects of this deepening on circulation, water quality, and biota, during and after the construction, the U.S. Geological Survey, in cooperation with the Tampa Port Authority, has collected data and developed a digital simulation model of the bay.

In addition to data collected using conventional tools, use is being made of data collected from ERTS-1. Return-Beam Vidicon (RBV) multispectral data were collected, while a shell dredging barge was operating in the bay, and used for turbidity recognition and unique spectral signatures representative of type and amount of material in suspension. The processed data integrated with other modeled parameters provide an overview of the dynamics of turbid material during dredging periods. A three-dimensional concept of the dynamics of the plume was achieved by superimposing the parts of the plume recognized in each RBV band. This provides a background for automatic computer processing of ERTS data and three-dimensional modeling of turbidity plumes.

1/ Messrs. Coker and Goodwin are Hydrologists, U.S. Geological Survey, Tampa, Florida, and Mr. Higer is a Hydrologist with the U.S. Geological Survey, Miami, Florida

Original photography may be purchased from:
EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

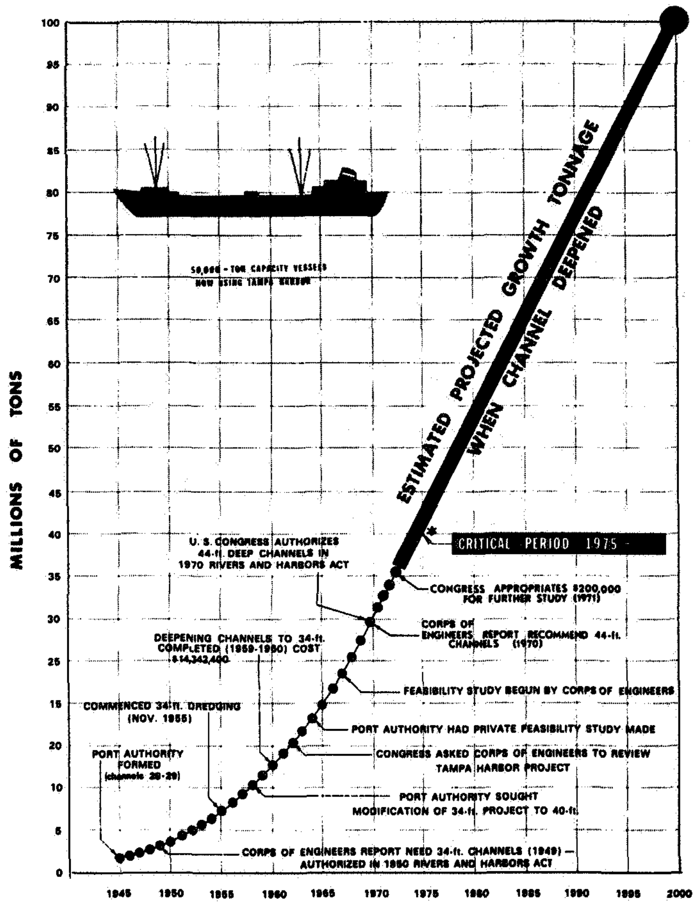
DETECTION OF TURBIDITY DYNAMICS IN TAMPA BAY, FLORIDA USING MULTISPECTRAL IMAGERY FROM ERTS-1

Background to Ongoing Estuarine Modeling in Tampa Bay

The Port of Tampa is the 8th largest in the nation with 36 million tons of total cargo handled annually. In terms of export tonnage, the port is 4th in the country with 11 million tons annually. Through this one port passes 50 percent of all the cargo tonnage in the State of Florida. This commerce provides 200 million dollars per year of wages and salaries to workers in the Tampa area, 15-18 million dollars per year to the U.S. Government in the form of customs receipts and, in addition, 50 million dollars per year to the positive side of the important balance of payments ledger.

In 1970, the Congress of the United States authorized the deepening of the channel (Rivers and Harbors Act of 1970) to 44 feet, mean low water (Figure 1). It is estimated that this harbor deepening will continue for 8 to 10 years before completion. Before engineering or construction can begin on such a long term project, however, public opinion and legislation require that the effect of the project on the environment must be predicted in advance to insure that adequate precautions will be taken to limit any adverse ecological effect and provide a means to evaluate alternative construction methods. To obtain this predictive ability and other necessary information, the Tampa Port Authority entered into a cooperative program with the U.S. Geological Survey to collect necessary physical, hydrodynamic, biochemical and other data to develop a sophisticated digital simulation model of Tampa Bay. This modeling program is underway and will be useful in predicting the effect of harbor deepening on circulation, water quality and biota during and after the construction period.

An extensive data collection program has been in operation for over a year to verify a model of this type. Time synchronous tidal elevations are being recorded every 5 minutes at 14 locations around the bay. Wind data from eight stations and water velocity data at 12 points are also being collected.



<u>Figure 1</u>. Projected growth for shipping tonnage and critical period of 1975 for Tampa Bay

Other data collection phases of the investigation included intensive biochemical analyses, analyses of sediment from the bay bottom, 32 water quality parameters, and definition of the bathymetry of the bay bottom by both water-borne, automated, depth-sounding equipment and aerial stereo compilation. Seismic surveys of the ship channel to locate sub-bottom strata have been run in conjunction with a test drilling program necessary for strata identification.

This background information and the carefully verified simulation model will permit predictions that will materially aid the wise management of Tampa Bay. To illustrate the output of the model, a frame from a preliminary time-lapse movie output generated by the simulation model is presented (Figure 2).

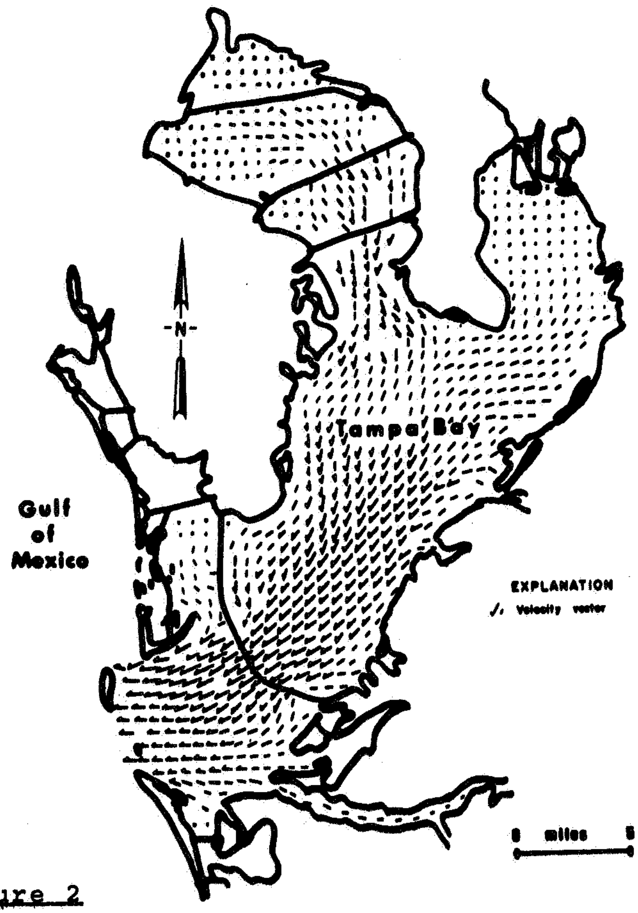


Figure 2

SIMULATED VELOCITY VECTOR GRID OF TAMPA BAY SHOWING OUTGOING TIDE WHEN CONDITIONS WERE SIMILAR TO ERTS OVERPASS ON AUGUST 2, 1972

This diagram delineates velocity patterns during a hypothetical ebb-flow condition similar to the time of Earth Resources Technology Satellite (ERTS) overpass made on August 2, 1972. The use of data from high-flying aircraft and spaceships provides a unique opportunity to monitor selected parameters using remote-sensing techniques that will aid the overall goal of environmental protection and enhancement while the main channel of Tampa Harbor is being deepened. The control of the concentration, dispersion and ultimate location of the fine-grained material introduced into the water by the dredging process, commonly called turbidity, is of utmost importance to the survival of many biological communities existing in Tampa Bay.

Objectives

A target of opporutnity was provided when ERTS imagery was recorded over Tampa Bay on August 2, 1972. The imagery was processed for turbidity recognition and integrated with the estuarine model to provide a method for synoptically observing and predicting the movement and distribution of turbid material caused by dredging operations.

Approach

Tidal stage data and wind measurements were acquired during a time when conditions were similar to the ERTS overpass of August 2, 1972. These data were edited, formalized and put into the digital model of Tampa Bay to produce the simulated velocity vector grid of the bay (Figure 2). At the same time a shell-dredging barge was operating in the bay. This dredging simulated turbid conditions that would be caused by channel dredging and the effects of tidal action on the movement and distribution of a turbidity plume (See Figure 3). Sampling for turbidity of bay water and near the shell dredging barge was acquired for ground-truth information and the analyses plotted (See Figure 4).

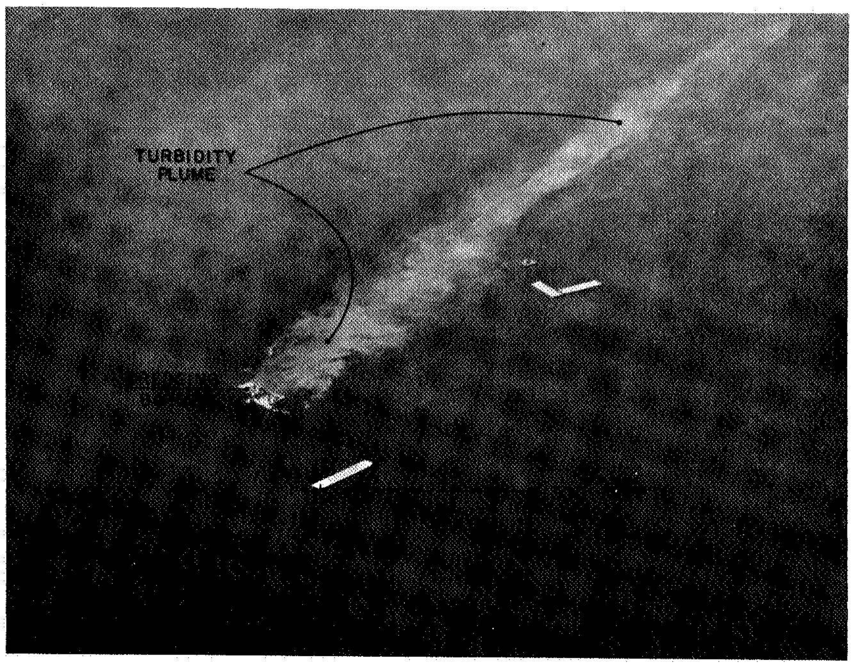


Figure 3 PHOTOGRAPH OF SHELL DREDGING OPERATION AND TURBIDITY PLUME

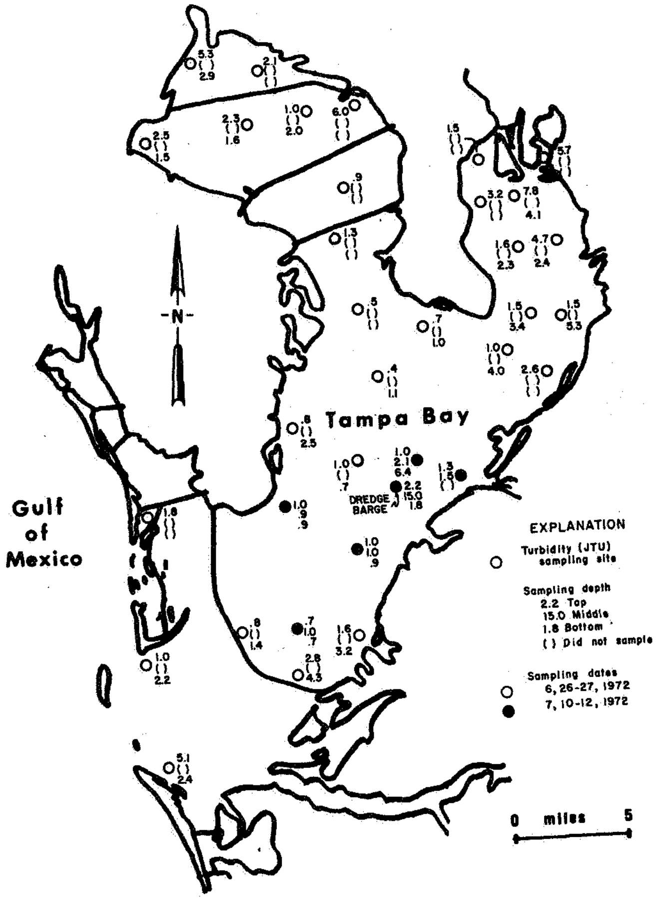


Figure 4. Sampling sites showing quality (turbidity) of Tampa Bay water and near a shell dredging barge

Black and white imagery transparencies from the ERTS Return-Beam Vidicon (RBV) multispectral three-camera system were taken over Tampa Bay on August 2, 1972. ERTS Image ID's are E-1010-15333-1, E-1010-15333-2 and E-1010-15333-3. This system operates in three different spectral regions, the green band 475 to 575 millimicrons; the red band 580 to 680 millimicrons; and the near infrared band 690 to 830 millimicrons.

Photo identification was made by comparing the transparencies, aerial photographs, maps and ground-truth information (Figure 4) of the bay with the velocity vector grid (Figure 2) and the imagery. The relative size and shape of the turbidity plume as recognized in each RBV band is illustrated in Figure 5. An appraisal of selectively singular bands for photo interpretation purposes to recognize and delineate selected estuarine features is presented in Table 1.

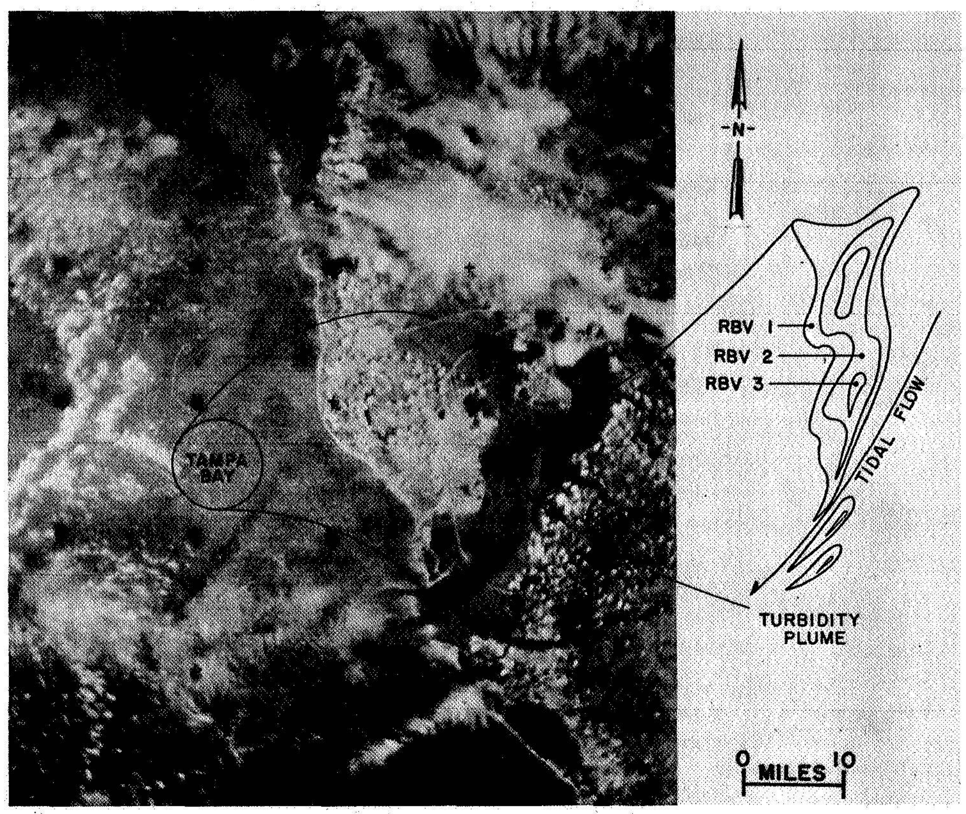


Figure 5 COLOR ADDITIVE ENHANCEMENT OF RBV IMAGES 1,2 AND 3 AND SKETCH OF TURBIDITY PLUME

ERTS Image ID E-1010-15333-1, E-1010-15333-2 and E-1010-15333-3.

Table 1. Estuarine Features That are Recognizable in the Imagery of ERTS RBV 1, 2, and 3 Bands

	RBV 1 Green	RBV 2 Red	RBV 3 Near Infrared
Differentiation of land from water features			
Maximum			X
Moderate		X	
Minimum	X		
Presence or absence of shoreline vegetation			
Maximum			X
Moderate		X	
Minimum	X		
Presence or absence of underwater features such as scour channels, vegetation and turbid flow (varies with turbidity)			
Maximum	X		
Moderate		X	
None			X
Aerial distribution of turbidity plume			
Maximum	X		
Moderate		X	
Minimum (at surface only)			X
Water penetration (varies with turbidity)			
Maximum	X		
Moderate		X	
None			X

An International Imaging Systems viewer was used to prepare a color additive enhancement of the turbidity plume from the three RBV black and white image separates. Colors were assigned as follows: RBV band 1 = blue, RBV band 2 = green and RBV band 3 = red. These images were simultaneously displayed on the viewer while color intensities were adjusted to produce a color composite enhancement of the turbidity plume. A black and white photograph of this enhancement is illustrated on Figure 5.

Analysis

Organic detritus and clay particles make up the major part of suspended particulate matter (turbidity) that results from dredging operations in the waters of Tampa Bay. The water absorbs and reflects sunlight so that the RBV imagery depicts a signature indicative of the turbid condition of the water. The intensity of reflection registered in the imagery will be modified by quantity and type of material in suspension, stratification and settling depth, type of bottom material and water surface roughness. If the water is clear or slightly turbid, the sun's energy that spans RBV-3 (longer wavelengths) is mostly absorbed at the surface, and that of RBV-2 and 1 will penetrate to progressively greater depths before being absorbed. For this water the resulting tones on positive black and white images will be almost black for band 3 with progressively lighter, but still dark, tones for bands 2 and 1. The lighter tones are caused by the greater penetration and scattering (less absorption) of light from suspended particulate matter in the water and atmosphere at the shorter wavelengths of bands 2 and 1. Depending upon the span of energy (RBV band), type of particulate matter, stratification, depth of settling and bottom conditions, the more turbid waters will be more reflective than the less turbid waters and will appear as lighter gray tones on the imagery.

On both RBV-1 and 2 positive images, the sediment plume is depicted by lighter gray tones near the center and darker tones of lower reflectance at the outer edges of plume. The turbidity plume boundaries in RBV-1 extend beyond those in RBV-2 or 3 and may be areas of deeper settling depths and/or contain less particulate matter in suspension (Figure 5).

The energy span of RBV-3 is mostly absorbed by water at the surface, and only the particulate matter at the surface reflects light. The part of the plume at the surface may be delineated by lighter gray tones in the imagery of this band. This part of the plume may also contain recently suspended material that may be more highly concentrated.

Assuming that the bay water is slightly turbid (Figure 4), a three-dimensional concept of the shape of the more turbid plume may be demonstrated by superimposing those parts of the plume observed in all three bands (Figure 5). The outer boundaries observed in band 1 may be at deeper settling depths than those of band 2 and/or contain less particulate matter in suspension. That part delineated by band 3 is near the surface, and the movement of the plume toward the mouth of the bay is in response to ebb tide conditions at the time of ERTS overpass (Figures 3 and 5).

Conclusions

Spectral signatures of gray scale tones indicative of turbid conditions of type, concentration, stratification, settling depth and area of dispersion were observed in the RBV imagery of Tampa Bay. The observed current patterns indicate that the plume moved toward the mouth of the bay in response to ebb tide conditions at the time of the ERTS overpass.

Preliminary studies indicate that ERTS imagery and computer-compatible tapes may be automatically processed in conjunction with associated ground information for quantifying these spectral signatures. The processed data may then be used as a tool for synoptically mapping and monitoring spatial and temporal conditions of turbidity and for comparing natural with manmade turbidity for appraising the resources of Tampa Bay and other estuaries. Furthermore, the processed data used in conjunction with the Tampa Bay digital simulation model may provide the basis for developing a three-dimensional concept to model the dynamics of turbidity plumes.

Prior to ERTS the extent of dispersion of dredging silt plumes in an area as extensive as Tampa Bay (over 300 square miles) could only be made by connecting stations of equal percent turbidity derived from a massive sampling program. However, the positions and number of transects for turbidity sampling did not usually allow complete synoptic coverage showing the dynamic distribution of the turbidity plume. Furthermore, compared with ordinary massive sampling programs, the associated ground-truth information needed for purposes of correlation with the ERTS imagery may be considerably reduced in number of transects and samples across the bay.

The channel deepening in Tampa Bay, as estimated, is scheduled to continue for 8 to 10 years. Comprehensive environmental appraisal studies are underway and programmed to continue during the construction period to continuously evaluate, monitor and guide the effects of dredging and disposal operations on the bay. The digital simulation modeling program of Tampa Bay is a part of these environmental studies. The synoptic and repetitive coverage of Tampa Bay by ERTS offers a timely opportunity to apply products of the space program to monitor and to help solve environmental problems such as those in Tampa Bay and other estuaries.