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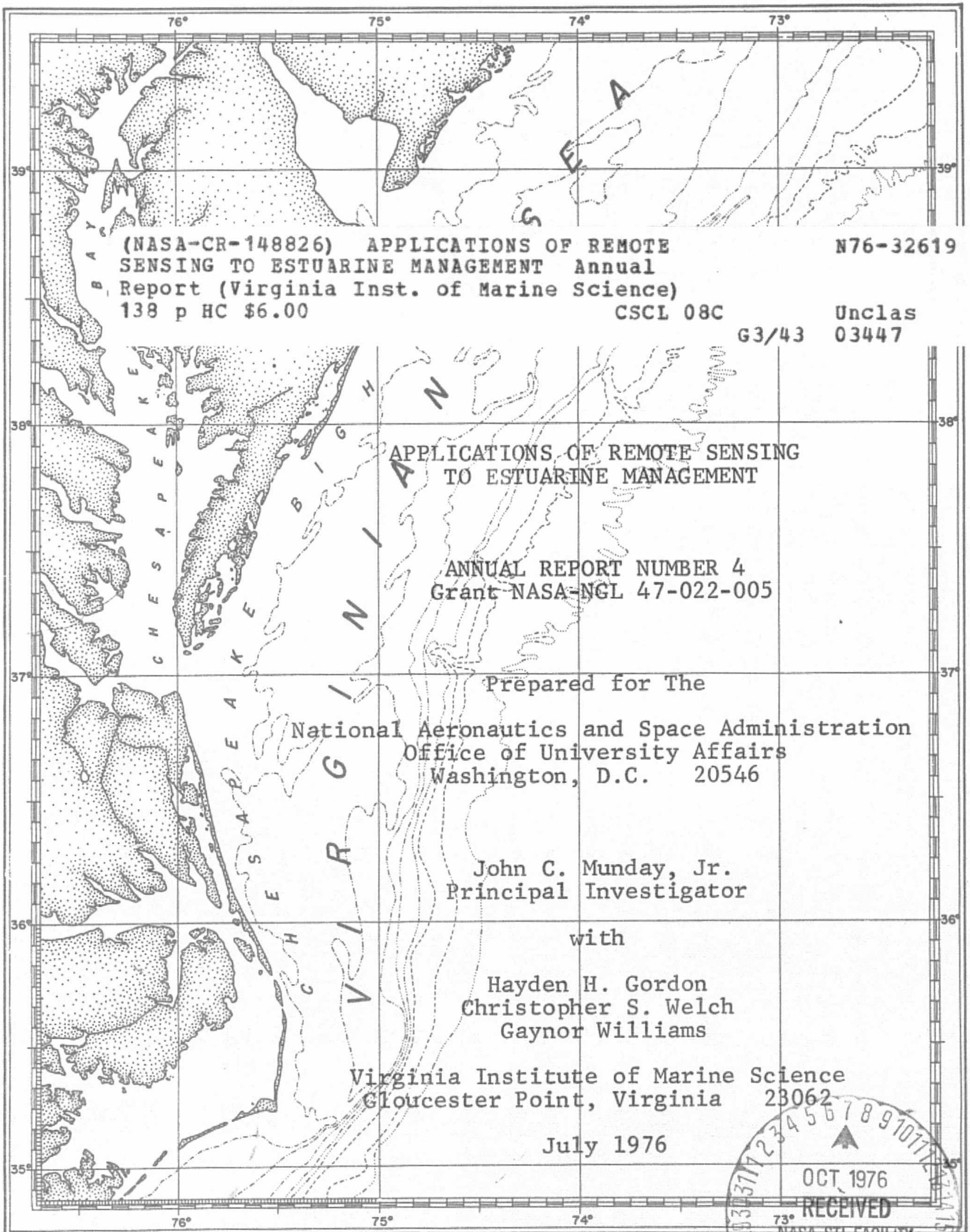

APPLICATIONS OF REMOTE SENSING TO ESTUARINE MANAGEMENT

ANNUAL REPORT NUMBER 4
Grant NASA-NGL 47-022-005

Prepared for The

National Aeronautics and Space Administration
Office of University Affairs
Washington, D.C. 20546

John C. Munday, Jr.
Principal Investigator

with

Hayden H. Gordon
Christopher S. Welch
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Virginia Institute of Marine Science
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ABSTRACT

New applications of remote sensing have been demonstrated for estuarine problems of the lower Chesapeake Bay by the Virginia Institute of Marine Science during 1975-1976. Demonstration projects included wetlands protection, pollution control, and sewage outfall siting.

A dye-buoy/photogrammetry and remote sensing technique was employed to gather circulation data used in outfall siting. This technique is greatly favored over alternate methods because it is inexpensive, produces results quickly, and reveals Lagrangian current paths which are preferred in making siting decisions. Wetlands data were obtained by interpretation of color and color infrared photographic imagery from several altitudes. Historical sequences of photographs were used to document wetlands changes. Sequential infrared photography of inlet basins was employed to determine tidal prisms, which were input to mathematical models to be used by state agencies in pollution control.

A direct and crucial link between remote sensing and management decisions has been demonstrated in the various projects. In siting a sewage outfall, sanitary authorities accepted a VIMS recommendation based on remote sensing to change the proposed site, in order to protect shellfish beds. Nearly one hundred acres of wetlands have been protected in various projects through the use of documentary remote sensing evidence. Thus, remote sensing is shown to have a critical impact on problems of estuarine management.

ACKNOWLEDGEMENTS

We gratefully acknowledge the support, encouragement, and direction of the National Aeronautics and Space Administration, Office of University Affairs, Washington, D.C., under the leadership of Dr. Joseph Vitale. Dr. John Oberholtzer of the NASA Wallops Flight Center, Wallops Island, Virginia provided helpful guidance and review. NASA Langley Research Center, Hampton, Virginia contributed use of photoanalysis facilities, and NASA Wallops Flight Center provided remote sensing imagery.

Many VIMS personnel contributed to field operations, data reduction, photo and art work, and secretarial assistance. We wish to especially thank Mr. Charles Alston, Mr. Hank Hennigar, Mr. Ken Thornberry, Mr. Joe Gilley, and Mrs. Cindy Otey.

FIGURES

TABLES

SUMMARIES OF APPLICATIONS OF REMOTE SENSING DURING 1975-1976

Completed by May 1, 1976

1. Pig Point Sewage Outfall Revisited

   Using remote sensing, VIMS selected a more northerly site for the Pig Point sewage outfall in Hampton Roads. This new site was adopted by the Hampton Roads Sanitation District Commission. It has also been accepted by the Virginia Bureau of Shellfish Sanitation which had objected to the earlier proposed site because of possible danger to shellfish beds. The new site is being included in the design plan and will be used for construction. The direct result of the remote sensing is that the critical seed oyster beds of Nansemond Ridge will be better protected from bacterial contamination.

2. Piankatank River Pollution Model Dye Study

   Erroneously high dispersion coefficients may result from boat transects leaving the dye patch during water pollution dye studies. Aerial photography and densitometry have been applied as the only method capable of locating and measuring errors.

   The Virginia State Water Control Board (SWCB) has given VIMS a contract to produce a mathematical model for circulation and dispersion in the Piankatank River. SWCB will use the model to make decisions for or against future pollutant inputs to the River. The VIMS model is being based on dye dispersion data obtained by boat-borne fluorometry, and will be submitted during summer, 1976. The correction based on remote sensing will have the effect of reducing the pollutant loading of the Piankatank River.

3. Jackson River Flood Control Planning

   Flooding at Covington, Virginia led Covington to request flood control by the U.S. Army Corps of Engineers. They proposed river bank modification which would involve loss of woodland. Remote sensing was selected as the cheapest and fastest way to evaluate the value of the proposed loss, to be compared with the value of flood control. Imagery was obtained and evaluation begun, but the decision whether to proceed with the modification has been held up due to lack of funds within the Corps.

4. Little Creek and Lynnhaven Non-Point Pollution Model Tidal Prism

   Panchromatic infrared photogrammetry is providing critical data for pollution control models for Little Creek and Lynnhaven Inlets. The Hampton Roads Water Quality Agency (HRWQA) has given VIMS a contract to produce mathematical models for circulation and flushing in Little Creek and Lynnhaven Inlets. HRWQA will use the models for decisions affecting land-use and aimed at pollution control. Critical numbers needed in the model are the tidal prisms of the associated Inlet sections; these numbers have been obtained from tide gauge data and water area data determined from panchromatic infrared photogrammetry at high and low slack waters. Remote sensing was the only way to obtain the water area data.

Recently a controversy arose that the model was invalid because of large water area changes; this argument was settled by the remote sensing which showed that area changes were small over a tidal cycle.

Thus, remote sensing justified use of the model and provided critical numbers used as input. The model is being tested and will be submitted to HRWQA for its use in late summer 1976.

5. Isle of Wight Non-Point Pollution Model Tidal Prism

Storm runoff is being evaluated with the aid of infrared photography. The Maryland Department of Natural Resources has contracted for development of a storm-runoff (non-point) pollution model. This model will be used in making land-use decisions, by providing quantitative data on water quality impacts due to proposed land-use changes.

Input data are required in 1976 as part of a Phase I contract to VIMS, which is providing data on water run-off and nutrient mass fluxes from eight land-use classes. The tidal-marsh class data have been obtained via water sampling, tide-gauge data, and water-area data from panchromatic infrared photogrammetry over a half-tidal cycle. The remote sensing method was chosen over a current meter method because all potential marsh inputs and exits were monitored, the time required for installation and maintenance of current meters was eliminated, and some channels were too shallow for the use of current meters.

Model development and testing as part of Phase II will be contracted by the State of Maryland in 1977.

6. Cedar Landing Estates Wetlands Destruction

Illegal alteration of a York County marsh has been proven from analysis of high-altitude N.A.S.A. photography, historical U.S. C&GS photography, and VIMS shoreline photography. The amount of marsh destroyed was roughly ten acres. The U.S. Army Corps of Engineers has initiated a suit against the developer, based on maps and interpretation derived solely from the photographs. The historical photographic sequence was the only available source of data.

7. Hampton Salt Ponds Wetlands Protection and Inlet Stabilization

A map of wetlands boundaries prepared by VIMS from a photogrammetric and remote sensing survey has resulted in change of a bayside development project by the City of Hampton, Virginia. VIMS conducted a remote sensing survey in cooperation with the City, mapping the remaining marshes, suggesting which marshes to preserve, and recommending structures to stabilize an inlet subject to deposition. In response, the City has revised its permit application.

The new application sets the limit to development at the marsh boundaries determined by VIMS remote sensing (with a protective setback distance). Proposed dredging is revised from 470,000 cubic yards below mean low water (MLW) to 88,000 cubic yards, and 130,000 cubic yards above MLW to 4,000 cubic yards, a total reduction of 85%. Channel depth is revised from 12 feet to 6 feet. New methods are proposed to stabilize dredge spoil in disposal areas, and to control sedimentation and erosion during dredging.

The VIMS remote sensing survey has thus resulted in major changes to the project plan, particularly the preservation of 60 acres of marsh. Remote sensing was the primary data source. It was essential for accurate up-to-date mapping. The new permit has been approved by VMRC, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and EPA. The approval of the Virginia State Water Control Board and the U.S. Army Corps is still pending.

8. Chapel Creek Wetlands Protection

The Mathews County Wetlands Board has rejected a proposed development at Chapel Creek, after VIMS used a photomosaic and photogrammetric measurements to show that a developer's proposed marina would result in direct destruction of one acre of marsh, and alter or threaten five additional acres.

Stereoscopic evaluation of the imagery revealed the presence of steep banks on the surrounding water body which would be eroded by boat wakes. The Board denied the development permit by a vote of 3 to 1.

The remote sensing was crucial to understanding the developer's hazy proposal, to allowing quantitative evaluation of the threatened marsh, and to convincing the Board of the fragility of the marsh and its setting.

Continued Into 1976-1977

9. York River Oil Slick Contingency Plan
   Data collection and reduction have been initiated for delineating currents and circulation in the York River. This information will be used to provide the AMOCO Refinery with strategy for deploying oil booms near convergence zones. The Refinery Director will order change in the AMOCO cleanup procedure, so as to better utilize currents and convergence zones in particular.

10. Elizabeth River Oil Slick Trajectory Prediction Circulation data for the Elizabeth River are being collected via remote sensing. Oil pollution trajectory maps will be constructed from these remote sensing data for oil spill cleanup strategy. The Coast Guard wants to use them to assist cleanup of frequent spills at pre-selected sites.

11. Dyke Marsh Restoration

Old marsh boundaries and marsh zones are being mapped from aerial photographs. The National Park Service plans to restore old boundaries with dredge spoil.

12. Hughlett Point Refuge Plan

The Army Corps, with assistance in photointerpretation from VIMS, is preparing a plan for a wildlife refuge in a woodland/marsh area. The Army Corps is waiting to implement the plan.

ASSISTANCE TO OTHER VIMS PROJECTS DURING 1975-1976

13. Coastal Shoreline and Dune Dynamics

Photogrammetry of shorelines and dunes of Virginia and North Carolina is being exploited to elucidate coastal dynamics. This research study, funded by the U.S. Coastal Engineering Research Center and assisted by remote sensing, will have significant impact on coastal land-use practices of both Virginia and North Carolina. Both states are assessing land-use policy in the controversial area below Back Bay National Wildlife Refuge. Aerial photography is a primary data source, along with field surveys, and ground control for new imagery.

14. Wetlands Permit Applications Evaluations

Continuing development pressure on Virginia wetlands is being met more and more often with analysis and interpretation of aerial photography. VIMS now reviews many wetlands permit applications forwarded from the Virginia Marine Resources Commission by means of aerial photography, which is faster than ground survey and permits quantitative measurements of marsh areas. VIMS personnel can make more informed recommendations to VMRC. This has a significant impact on wetlands protection because VIMS recommendations are generally accepted without alteration by VMRC.

15. Fishermans Island Vegetation Mapping and Erosional History
Astonishing changes in the morphology of Fishermans Island at the mouth of Chesapeake Bay have been mapped by VIMS from old and new aerial photographs. The Director of the National Wildlife Refuge on the Island has declared these findings have forced him to adopt a new management policy of permitting natural changes to occur unimpeded.

PART ONE: INTRODUCTION

1. CHESAPEAKE BAY ESTUARINE MANAGEMENT

The estuarine resources of the Chesapeake Bay system have long held the attention of various state and federal agencies. Before the development of the present wave of environmental and ecological concerns, regulatory and advisory bodies had been established in order to promote orderly and balanced use of resources. In Virginia, an early emphasis was on fishery resources, which led to the establishment of the Virginia Fisheries Laboratory in 1941 (converted to the Virginia Institute of Marine Science in 1962).

The new awareness in the 1960's of the fragility of ecological systems, and the prime importance of estuaries in coastal ecology, led to a great expansion of programs and regulations. Because of this great expansion, there developed an overlap of interests, and a complexity of relationships between agencies. Even multi-state and multi-institution consortia have come into being to focus on the Chesapeake Bay as a system. However, no new governmental bodies of note have been formed.

One might conclude that the proliferation of programs in several agencies is a haphazard approach to the environmental needs. However, it may be argued in response that the fastest way to start building on the new scientific awareness of ecology has been first to expand existing organizations, rather than attempt too early to organize new governmental efforts and substantially restructure existing ones.

The most recent announcement of interest for the Chesapeake Bay is that, as of June, 1976, the U.S. Environmental Protection Agency plans a significant expansion of its efforts with respect to preserving the Chesapeake Bay. The EPA plans an expenditure of $5 million (compared to $257 million authorized by the U.S. House of Representatives for EPA research and development activities in fiscal 1977). At the same time, offshore oil exploration activities and related onshore Bay developments will involve hundreds of millions of dollars. The national and local response to Chesapeake Bay needs may yet be too limited.

2. MISSION OF THE VIRGINIA INSTITUTE OF MARINE SCIENCE

The Virginia Institute of Marine Science is obligated by statute of the Commonwealth of Virginia to perform marine research and provide marine advisory services to the Commonwealth. To this end the Governor has designated the Institute as the Coastal Zone Laboratory of the Commonwealth, making it a focus for not only marine science but also coastal issues which involve or have an impact on the Commonwealth marine environment. The Institute has no regulatory function; it responds to questions posed by regulatory and other agencies, and brings to their attention questions which need to be addressed.

The Institute administers an academic program leading to the award of advanced degrees in fields of marine science, by affiliation with the College of William and Mary and with the University of Virginia.

With the growth in recent years of federal government funding in environmental science, the Institute now obtains 75% of its funds from non-Commonwealth sources. Nevertheless, the Institute still adheres in the acceptance of such funds to the mission as prescribed by the Commonwealth. As presently situated, the Institute functions in relationships with all federal, state, and local governmental agencies, and with industries and consulting engineering firms, which are involved in issues pertaining to the marine and coastal environment.

The Chesapeake Bay and its estuaries comprise the dominant marine resource for the Commonwealth of Virginia. Management of the Bay estuarine system is therefore a principal concern for the Commonwealth. Thus, most of the Institute research and environmental assessment is directed toward Chesapeake Bay estuarine management.

3. THE ROLE OF REMOTE SENSING IN ESTUARINE APPLICATIONS AT THE VIRGINIA INSTITUTE OF MARINE SCIENCE

The history of remote sensing at the Institute began in the middle 1960's with the advent of NASA and other funding to some staff members. The remote sensing work at that time was primarily oriented to geological and physical oceanography research. In 1970, NASA Wallops Flight Center began to support a variety of applications of remote sensing in marine science programs at the Institute. Shortly after the beginning of the Wallops Program, a Remote Sensing Section began to assume shape within (what is now) the Division of Physical Sciences. During the Wallops program, which lasted four years, research was conducted in oil slick detection and measurement, thermal effects from the Surry nuclear power plant on the James River, and densitometric/view-angle variations in wetland imagery as a limiting factor in automated machine species identification and biomass determination. In a separate NASA Johnson Space Center contract through the Skylab program, satellite multiband photography and multispectral scanner data were analyzed by computer processing for discrimination of marshes, and for correlation with commonly measured water parameters.

The present NASA Washington grant began in 1972 with an emphasis on the use of remote sensing to collect circulation data important in a variety of estuarine and coastal problems. Remote sensing has been used to solve problems including sewage outfall siting, shoreline preservation and enhancement, oil pollution risk assessment, protection of shellfish beds from dredge operations, and wetlands protection.

A particularly useful byproduct has been the development and utilization of a technique to determine surface current trajectories using photogrammetry of dye-emitting buoys. The necessary aerial photography is obtained with VIMS aircraft and cameras, and analyzed using standard photointerpretation and photogrammetric techniques. Trajectories are then analyzed with respect to the problems being addressed, and specific recommendations are prepared for coastal zone estuarine managers.

VIMS uses a variety of its own photointerpretation and analysis devices, and has continuing permission to use instruments at the nearby NASA Langley Research Center and at the NASA Wallops Flight Center. This year, we have developed a photolibrary indexed for fast retrieval. The library contains VIMS photography, NASA aircraft photography and scanner imagery and LANDSAT imagery.

The staff of the Remote Sensing Section consists of four full-time employees and two part-time employees. About ten other staff members routinely employ the remote sensing capability in related contracts, and contribute to long-term remote sensing development.

The present emphasis in the Remote Sensing Section is to carry out demonstration projects in which remote sensing plays a crucial role in leading to an estuarine management decision.

After one or more demonstration projects in a given application area have been successfully completed, support for additional projects is fully transferred to the benefitting agency.

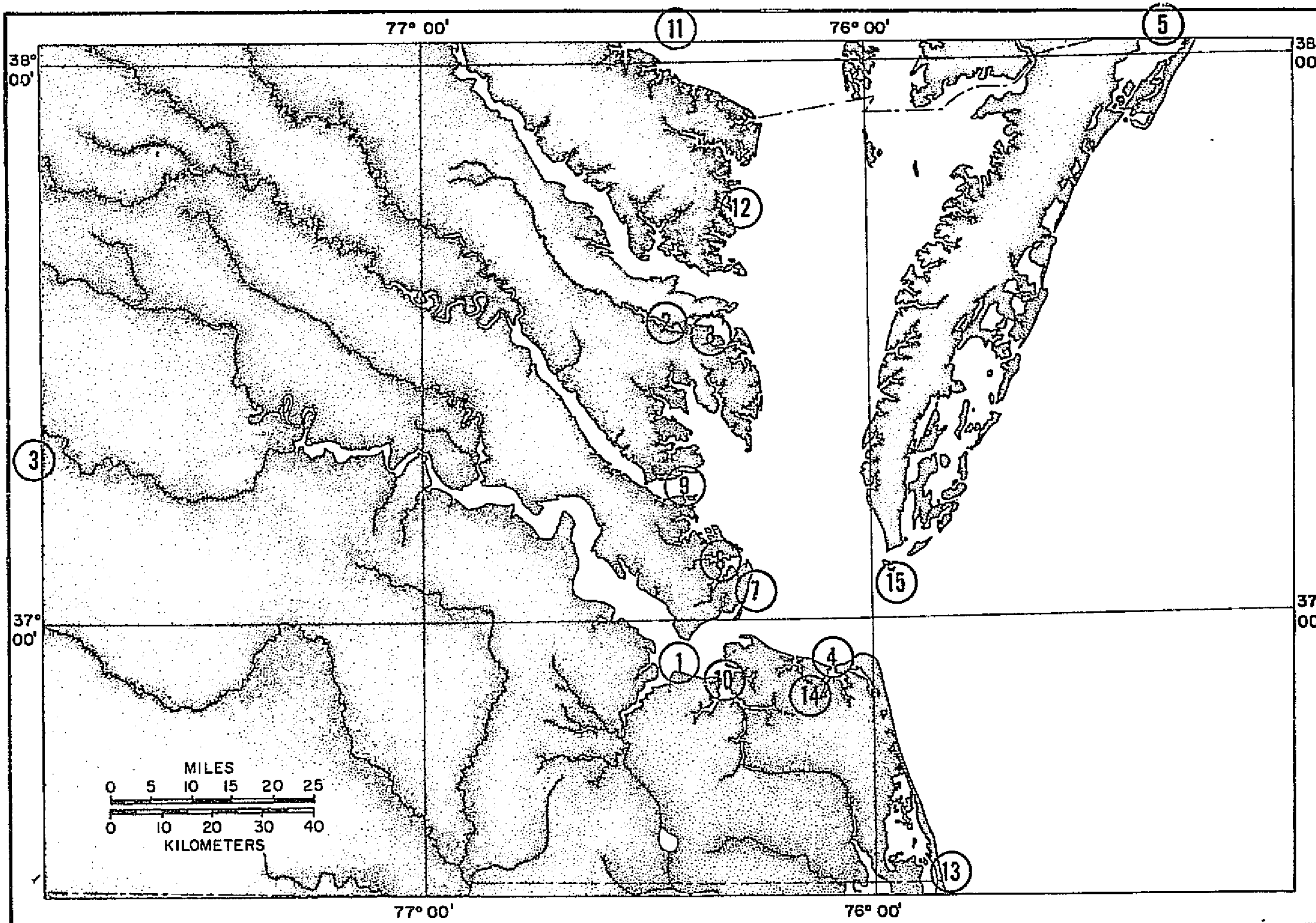
Projects involving remote sensing have generally involved the application of existing remote sensing technology and methods. Inasmuch as the problems addressed by the Institute are complex, involving scientific, economic, and political factors, it has been rare for a problem to have a solution based solely on remote sensing. Nevertheless, this report shows that it has been possible to concentrate on problems in which the role played by remote sensing is important. Remote sensing has now been established as a standard method in solving Virginia's marine problems. In the past, before the support from NASA began, the use of remote sensing was almost nonexistent.

Remote sensing methods are described in Part Two. In the discussion of applications in Parts Three and Four, each application is described in a self-contained chapter, according to the list in the Table of Contents. A summary of the applications is given in Table I. Figure 1 shows the application sites on a regional map.

TABLE 1 SUMMARY OF APPLICATIONS FOR 1975-1976.

APPLICATION	STATUS/OUTCOME	USER LINKAGE	REMOTE SENSING METHOD	ORIGIN OF FUNDING
Complete by 1 May 1976				
1. Pig Point Sewage Outfall Revisited.	Recommended change of proposed outfall site approved.	VIMS → consulting firm → HRSD, Va. Bur. Shellfish San.	Dye buoy photogrammetry. 1:30,000.	Consulting firm, HRSD, NASA grant.
2. Piankatank River Pollution Model Dye Study	Better dispersion coefficient. Model for VSWCB under development.	VIMS → Va. State Water Control Board	Photo densitometry. 1:30,000.	Va. State Water Control Board, NASA grant.
3. Jackson River Flood Control Planning	Corps evaluated potential tree loss. Corps project in abeyance due to lack of funds.	VIMS → Army Corps of Engineers	Color infrared photography. 1:12,000.	U.S. Army Corps of Engineers, NASA grant.
4. Little Creek and Lynnhaven Pollution Model Tidal Prism	Tidal prisms measured. Models for HRWQA under development.	VIMS → Hampton Roads Water Quality Agency	Pan infrared photography. Planimetry 1:36,000.	Hampton Roads Water Quality Agency, NASA grant.
5. Isle of Wight Non-Point Pollution Model Tidal Prism	Tidal prism measured. Model for Md. under development.	VIMS → Md. Dept. of Natural Resources.	Pan. infrared photography. Planimetry.	State of Md., NASA grant.
6. Cedar Landing Estates Wetlands Destruction	History of Estates development uncovered. Litigation by Army Corps pending.	VIMS → Army Corps of Engineers	Photo interpretation. NASA, USDA, new photography 1:12,000.	NASA grant.
7. Hampton Salt Ponds Wetlands Protection & Inlet Stabilization	60 acres of wetlands protected. Design recommended for jettys to stabilize inlet. City of Hampton seeking permit.	VIMS → City of Hampton	Wetlands and inlet mapping. Old maps and new 1:18,000 photography.	NASA grant.
8. Chapel Creek Wetlands Protection	Marina development rejected by Mathews County Wetlands Board. 5 acres wetlands protected.	VIMS → Mathews County Wetlands Board	Photo interpretation of USC & GS and new 1:12,000 photography.	NASA grant, VIMS Wetlands Section
To Be Continued Into 1976-1977				
9. York River Oil Slick Trajectory Prediction	Data gathering underway.	VIMS → AMOCO	NASA imagery, VIMS dye buoy Photogrammetry.	NASA grant.
10. Elizabeth River Oil Slick Trajectory Prediction	Data reduction in process. New experiments underway.	VIMS → U.S. Coast Guard	VIMS dye buoy Photogrammetry.	NASA grant.
11. Dyke Marsh Restoration	Photo interpretation in process.	VIMS, NASA Wallops → Natl. Park Service	Photo interpretation of historical imagery	NASA grant, VIMS Wetlands Section, NASA Wallops.
12. Hughlett Point Refuge Plan	Photo interpretation in process.	VIMS → Army Corps of Engineers, private landowner	Photo interpretation of historical and VIMS imagery.	NASA grant, U S Army Corps of Engineers
Assistance to Other VIMS Projects				
13. Coastal Shoreline and Dune Dynamics	Dune migration under study.	VIMS Dept. Geological Oceanography	Photogrammetry of imagery of various scales	U.S. Coastal Eng. Res. Center, NASA grant.
14. Wetlands Permit Applications Evaluations	Evaluations proceeding (300/year); calls for aerial photography increasing.	VIMS Remote Sensing Section → VIMS Wetlands Department	Photo interpretation of new imagery 1:6,000	Commonwealth of Virginia, NASA grant.
15. Fishermans Island Vegetation Mapping and Erosional History	Large changes caused refuge manager to avoid stabilization attempts.	VIMS Dept. Geological Oceanography → Fishermans Island Natl. Wildlife Refuge	Photo interpretation of NASA imagery	VIMS, NASA grant.

Figure 1. Sites of demonstration projects for 1975-1976. The encircled numbers refer to entries on Table 1 (preceding page) and to chapters in Parts Two and Three.



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P A R T T W O : M E T H O D S

1. FIELD OPERATIONS

Field operations in support of Remote Sensing projects typically utilize an aerial platform for acquiring nadir and oblique photography, and often a ground crew operating in a boat for a coordinated program with the aircraft. An aerial platform used to remotely sense the marine environment must be stable for acquiring good imagery, easily deployed to take advantage of opportunities dictated by weather, and have an endurance in excess of six hours to record events regularly over one-half of a tidal cycle. For operations in conjunction with a ground crew, good communications are necessary.

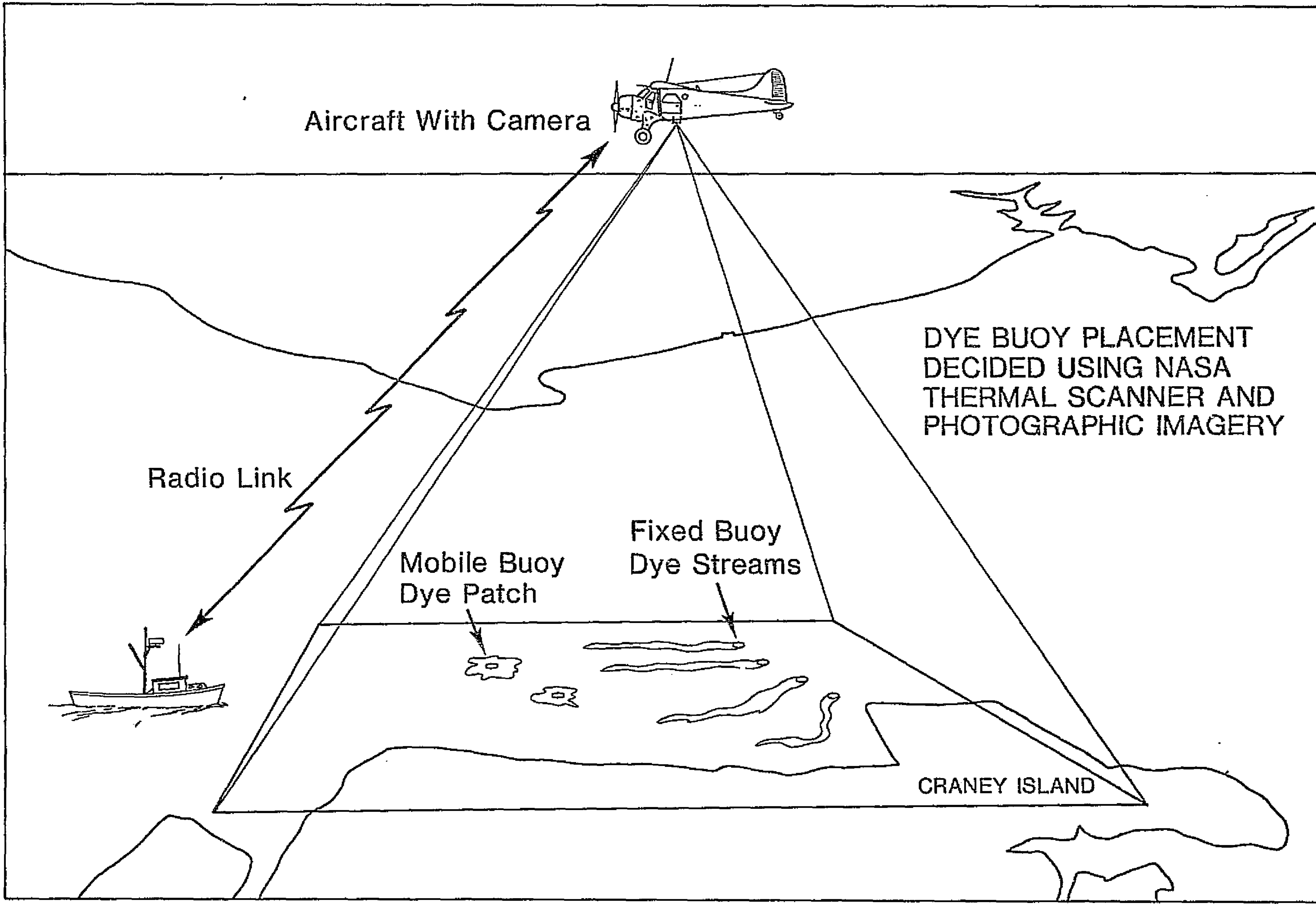
The key to remote sensing in the marine environment is to be able to react quickly to take advantage of windows which are strongly time dependant. Certain circulation features in a tidal estuary may persist only for a matter of hours. Sources of oil, for example, may be quickly masked by tidal movement and a resulting slick may beach at a seemingly unrelated location. Photography of man-made changes in wetlands and shorelines often must be taken within several days to mark activity in progress. Studies which utilize aerial photography of dye-emitting buoys for current trajectories are constrained by tidal phase, wind velocity and direction, and acceptable weather. Consequently, remote sensing personnel and equipment must remain in a ready state continuously for problems requiring aerial photography, and a complicated air-ground effort must be organized within a week and remain ready for deployment on a daily basis for up to a week. The most important elements of the field operations are the aircraft, the photography, and communications. These are described below. Figure 2 illustrates the elements of a typical VIMS remote sensing operation.

AIRCRAFT

VIMS is fortunate to have a dedicated aircraft, on loan from the Army via the Navy, to fulfill the needs of remote sensing, as well as to transport personnel and equipment for the Institute. The aircraft is an Army U-6A DeHavilland Beaver manufactured in 1953. It is a five place single engine airplane powered by a 450 horsepower 9 cylinder Pratt and Whitney radial engine. The aircraft has a useful load of 2,000 pounds of fuel, passengers, and cargo. Attributes which make the aircraft particularly useful for remote sensing are an integral photography port in the aft with an 18-inch diameter opening, and ample room for equipment and personnel. Seats are easily removable, leaving a large clear deck for photography and communications. The aircraft has an intercom system enabling the pilot, copilot, and photographer to communicate from their respective locations. With a full load of fuel, low power settings, and a three man crew, the aircraft is capable of remaining on location continuously for more than eight hours. With relatively large wings and small wing loading the aircraft is very stable, and roll and pitch changes due to

Figure 2. Features of dye buoy remote sensing.

DYE BUOY REMOTE SENSING



turbulence can be minimized. The aircraft is based at an airport which can be reached in 15 minutes from the Institute, and can be deployed within one-half hour.

PHOTOGRAPHY

Sensors used for aerial photography are a 70 mm format motorized Hasselblad 500 EL/M camera fitted with a wide angle 50 mm focal length Distagon lens, and a Nikon F2 Photomic 35 mm format camera with a 55 mm focal length Micro Nikkor lens. Both cameras can be used simultaneously in a mount with single axis compensation for aircraft pitch changes. The Nikon camera serves in conjunction with a Kodak Aerial Exposure Computer to determine the proper exposure for aerial photography.

Kodak ER 5257 color reversal film is generally used for mapping applications. This is a 70 mm bulk load form of the widely used Kodak High Speed Ektachrome slide film (ASA 160 speed), and permits photography from heavily overcast days (f/4, 1/250 second) to bright sunny days (f/16, 1/500 second). This film does not have an Effective Aerial Film Speed rating, but in our experience the EAFS is roughly 40 to 60. The resolving power is 60 line pairs per mm at a contrast of 1000:1 and 30 lpmm at 1.6:1. A square white target, 0.5 meter on a side, is observed on the film without magnification when photographed from altitudes up to 1500 m.

The Nikon camera is generally loaded with Kodak Vericolor II Professional film yielding color negatives for making color prints.

Other films which are used for special applications include Kodak 2424 High Speed B & W Infrared film for discerning land/water boundaries, Kodak 2443 Color Infrared film for vegetation mapping, and Kodak SO-224 Water Penetration film for subaquatic vegetation mapping. VIMS has the facilities to process black and white films in 35 mm and 70 mm when necessary for immediate viewing.

An intervalometer is on order for the Hasselblad to facilitate automated framing to realize fixed frame overlap over long flight lines.

COMMUNICATIONS

Communications are used whenever aerial photography requires the presence of a ground crew to deploy dye markers or take samples. In fact, communications are of primary importance to aerial surveys using dye emitting buoys to plot current trajectories. Communications are used to vector the boat crew to dye markers not visible from the water (unless the boat is in close proximity). Dye markers can thus be retrieved to be redeployed elsewhere, or serviced if necessary. Communications from the boat to the aircraft serve to identify dye buoys by number for absolute correlation with aerial photography. The capability of communicating is also very useful when it is necessary to modify a field effort in progress as conditions dictate.

The present communications system consists of a 23-channel 5-watt citizens band transceiver mounted in the aircraft, with the audio wired into the intercom system. The photographer is thus in contact with the pilot of the airplane and boat crew simultaneously. The boat presently uses a walkie-talkie with six crystal controlled channels and a special 2.4 meter fiberglass marine antenna. This system is portable and can be used on any type of boat best suited to a particular study. A second walkie-talkie is also available when three-way communications are necessary.

2. DATA REDUCTION

Data reduction of aerial information gathered by VIMS or NASA takes the form of photointerpretation, photogrammetric measurements, or density analysis. Computer work is done through the VIMS computer center, and CALCOMP plotting is done at the College of William and Mary.

Some of the problems requiring use of VIMS and NASA facilities are the measurement of wetland areas and area change, shoreline length including erosion or accretion, average velocity of surface and subsurface currents from dye markers, plotting of convergence zones, foam lines, and other surface visible singularities, and correlations of photo density with dye concentration.

Data reduction techniques most commonly employed require mapping, map revision, digitizing, planimetry, length measurement, and densitometry. Instrumentation to achieve this is briefly described.

All mapping is now done at VIMS with the acquisition of a Bausch and Lomb Zoom Transfer Scope, Model ZT4-H. The basic principle of the instrument enables an operator to view two materials, such as a photo and a map, in superposition. A map or a photo is placed on a horizontal piece of glass and is viewed simultaneously with a base map on a drawing surface. Common features on both are used for scale adjustment, after which features from the map or photo can be drawn directly on the base map as desired. The instrument will match scale from the photo (map) to the base map within a range 0.2 to 18.

Digitizing, planimetry, and length measurement is now done at VIMS with the acquisition of a Numonics Graphics Calculator. The instrument works over any flat surface 0.5 meter on a side and digitizes to a resolution of 0.25 mm. The coordinate origin can be set anywhere within the work area. Lengths and areas are measured and automatically scaled using five preset options (options are easily changed by inserting a different circuit board). The instrument will allow further modification of the scaled answer using a multiplier from 0.01 to 99.9. With careful use the instrument will measure length and area to 1% accuracy.

Densitometry is done at VIMS using a Brumac Industries spot densitometer with a 1, 2 or 3 mm aperture. Densitometry which requires raster scanning, digitization, iso-density contour plotting and/or smaller apertures can be done at NASA Langley Research Center or NASA Wallops Flight Center.

New computer programs have been developed to aid data reduction involving large amounts of data. Programs are run locally at VIMS on an IBM 370-135 computer, or at the College of William and Mary an IBM 360 system which is larger and offers a plot capability. New programs include a program for manipulating buoy data, preparatory to generating maps of current vector fields, and a map (drawing) program.

The map program permits the mapping of shoreline and shore feature information to any desired scale for use as field maps, base maps on the Zoom Transfer Scope, and maps for reports. Topographic 7.5 minute maps typically offer the most up-to-date information available for use as base maps in aerial mapping. These, however, are often too large to use easily on the Zoom Transfer Scope, at the wrong scale for use with typical 70 mm imagery, too large to take into the field, and lacking data on placement of navigational aids. Therefore, use is made of the recording coordinate digitizer at NASA Langley to generate a deck of cards with the x-y location of the shoreline (at an interval of approximately 0.02 mm), easily recognized features near the shore, navigational aids in the water, and a grid (such as the Universe Transverse Mercator). Information can be digitized from maps of different scale and kept in small decks of computer cards. The cards are then processed by the computer program, the scale change for each deck chosen, and a composite map with desired information from each original map used plotted to a common user--chosen scale. The overlay capability allows flexibility in making maps which contain sufficient information for a variety of purposes. Scales are limited only by paper size. The cost is significantly less than that via the overburdened VIMS Art Department, and the turnaround time is shortened to one or two days.

3. PHOTO LIBRARY AND RETRIEVAL SYSTEM

In the past few years the VIMS Remote Sensing Section has obtained much NASA imagery and recently has been generating much of its own. As the imagery and services provided by the Remote Sensing Section have become more popular it has become necessary to organize the method of film accession. Several months of effort has finally accomplished the goal of a photo index system.

The method of indexing was devised and implemented in the Remote Sensing Section. The basis consists of two maps: a 1:250,000 series of topographic maps prepared as a Chesapeake Bay mosaic for VIMS imagery, and a 1:1,000,000 scale topographic map for NASA imagery. Other components include one file drawer containing summaries of missions and flights for VIMS and NASA, photo log books, mission books, and, of course, the imagery itself. The imagery is mainly 9 in. format rolls of NASA film and 70 mm format rolls of NASA and VIMS film.

Both of the maps cover the entire Chesapeake Bay area including all tributaries and the Eastern Shore. Both are segmented by a grid system, the VIMS map using the 1000 m UTM (Universal Transverse Mercator) system, and the NASA map using 15 minute quadrangles. The reason for two maps is that VIMS missions are relatively low altitude, small area coverage, and confined to a few UTM grid boxes. NASA flights are high altitude with flight lines sometimes extended from one end of the Bay to

Figure 3. Forms Used in Photo Library and Retrieval System.

(a) Summaries of Missions

(b) Flight summary

Mission Number: ____________ Date: ____________

Project Name: ____________

Location: ____________

Film Type: ________ Scale: ________ Library Number: ________

Mission Number: ____________ Date: ____________

Project Name: ____________

Location: ____________

Film Type: ________ Scale: ________ Library Number: ________

Mission Number: ____________ Date: ____________

Project Name: ____________

Location: ____________

Film Type: ________ Scale: ________ Library Number: ________

Mission Number: ____________ Date: ____________

Project Name: ____________

Location: ____________

Film Type: ________ Scale: ________ Library Number: ________

Mission Number: ____________ Date: ____________

Project Name: ____________

Location: ____________

Film Type: ________ Scale: ________ Library Number: ________

(a)

Flight Summary

Mission Number: ____________ Date: ____________

Project Name: ____________

Location: ____________

Purpose of flight: ____________

Sensors: ____________ Library Number: ____________

Aircraft: ____________ Pilot: ____________

Photographer: ____________ Navigator: ____________

Altitude: ____________ Cloud Cover: ____________

Temperature: ____________ Humidity: ____________

Visibility: ____________ Surface Wind: ____________

Sensor Data

Cassette Number/s: ____________

Film Type: ____________

Spectral Band: ____________

Scale: ____________

Lens focal length: ____________

Filter: ____________

No. of frames: ____________

Additional Information: ____________

(b)

the other. The smaller scale of the NASA map with a larger area grid serves to minimize the number of grid boxes needed for indexing the NASA imagery. On each map columns are identified by letters of the alphabet, and rows by numbers.

The file drawer contains five separate sections: VIMS Summary of Missions Section, VIMS Flight Summary Section, NASA Summary of Missions Section, NASA Flight Summary Section, and the VIMS Log Book Section.

The Summary of Missions Section is accessed by a letter-number grid box reference chosen from one of the maps (NASA or VIMS). Example: Imagery for Box A-28 on the NASA map would be found on page A-28 in the NASA Summary of Mission section, File A. The Summary of Missions pages (see Fig. 3a) inform the user of the mission number, flight number, date of flight, film type, photographic scale, exact location, and the film library roll number(s). Using the library number(s) the user can directly retrieve the film.

For more detail, if needed, the user can consult the Flight Summary Section. It is accessed from the Summary of Missions Section using digits in the mission number. The Flight Summary pages (see Fig. 3b) give the user more information about the mission and the film. Also contained in this file are flight line maps in color print format of topographic maps, with squares indicating area of frame coverage. Using these maps the user can determine if the area of interest was covered in the given flight. The Flight Summary Section repeats the film library roll number. It also includes the original camera cassette number for reference to original notes in the log books and mission outlines. Formerly, the log books were carried on each flight for direct data input. Now, log books are kept in the library for continual accessibility, and log data are transcribed into them from magnetic tape recordings made during flights.

The following is a list of definitions to further clarify the index and retrieval system:

Mission Number: For VIMS imagery, this number consists of the last two digits in the year the mission was started, a number assigned to the mission, and the flight of the mission. Each separate date is a new flight (ex. 74-01-02). For NASA Johnson and Ames imagery, it is the number NASA has assigned to the mission, the number NASA has assigned to a particular site, such as the Chesapeake Bay area, and the flight number which may consist of a series of flights over an area, on possibly different dates (ex. 187/224/13). For NASA Wallops imagery, there is simply a prefix "W" followed by three digits indicating the number NASA has assigned to the mission (ex. W226).

Project Name: Title given, usually by location, to a series of flights (comprising a mission)(ex. Pig Point Dye Study, Central Atlantic Coastal Area).

Film Library Roll Number: The accession number for the roll of film on the library shelf. Each library number is assigned a letter prefix dividing NASA from VIMS imagery.

A - NASA film shelves

B - VIMS film shelves

Film Type Code: The film type code is listed on flight summaries.

HSE - Hi-Speed Ektachrome

EK - Normal Ektachrome

KR - Kodachrome

IR - Black & White Infrared

CIR - Color Infrared

LX - Plus X

NX - Pan X

DX - Double X

TX - Tri X

Cassette Number: This number is the number originally assigned to the cassette of film employed in the camera during exposure. It links the film to the original notes in the log book. For NASA it is the number that was assigned each roll of film for a particular mission. This number can be traced back into the NASA mission summary outline books.

PART THREE: DEMONSTRATION PROJECTS

1. PIG POINT SEWAGE OUTFALL SITING

THE PROBLEM

During 1974, VIMS conducted studies for the outfall from the proposed Nansemond Wastewater Treatment Plant at Pig Point on the southern side of Hampton Roads (VIMS, 1975). The studies involved dye releases from the munitions loading pier known as "Foxtrot", which is near the originally proposed location of the outfall. A revised proposal was then formulated by McGaughy *et al*. (1975), the engineering consultants, with a new outfall location roughly one kilometer to the east of Foxtrot. Because tidal circulation in Hampton Roads is quite complex, there was concern that distribution patterns for the material released at the two sites would differ considerably. Particularly, there was concern that effluent released at the new site would contaminate highly productive oyster grounds on Nansemond Ridge, located off Barrel Point and to the north of the Nansemond River channel. Hence, an additional study was proposed to investigate dispersion characteristics of the new site compared to the original site.

THE USE OF REMOTE SENSING

The earlier VIMS study, using a release of Rhodamine dye over a half tidal cycle (Kuo and Jacobson, 1975) had adequately determined large-scale and long-term dispersion of the proposed effluent. For the fine-scale short-term information critical to the particular concern, the dye buoy/remote sensing method was chosen because of low cost, rapid execution, and comprehensive coverage of the critical areas. In retrospect, the two techniques form an excellent complementary pair for obtaining empirical descriptive predictions of expected dispersion patterns over all important time and area scales in tidal estuaries.

METHODS

An estimate of the tidal excursion for this region was obtained by volumetric considerations. The intertidal volume of the Nansemond River was presumed to flow as a slug of water from Hampton Roads, and from the size of the slug, a preliminary assessment made of the potential for water from the proposed outfall location to reach the Nansemond River. The results of this crude calculation indicated that further study was needed to determine if water flowing past the proposed outfall site would enter the Nansemond River or pass over the oyster grounds of Nansemond Ridge.

After initial experimentation, a full experiment was conducted on August 28, 1975. Streamer (fixed position) dye buoys were located at various distances from shore along the proposed route of the outfall pipe and past the proposed outfall site. Floater (Lagrangian) dye buoys were released at chosen sites on the rising phase of a flood tide, at hourly intervals. Aerial photographic runs recorded dye plume locations on 70 mm color film at short intervals. Figure 2 is an example of the imagery. To provide a location reference when buoys drifted into open water areas, the study boat anchored during photography and obtained a several minute sequence of Loran C positions to fix its position.

Buoy positions were plotted on photocopies of topographic maps using a Bausch & Lomb Zoom Transfer Scope. Experience indicates that the position accuracy using this method is a radius of 10 m using 70 mm film and a 50 mm lens from 1500 m altitude. UTM coordinates accurate to 5 m were read and reduced to buoy trajectories.

RESULTS

It was concluded that the flow past the outermost sites would be directed during early flood tide toward but not reach the mouth of the Nansemond River. The early flow past the inner sites would beach on the Nansemond County shoreline during northeast to west winds. Because the flow from the outer sites passed north of Foxtrot, later in the flood, it was concluded that the effect on the Nansemond River and Nansemond Ridge areas would be less than that reported for the dye study conducted in 1974 at Foxtrot, if the outfall were located north of 36°56'N.

Based on the conclusions, VIMS recommended that any sewage outfall constructed in the area between Foxtrot, Newport News

Figure 4. Dye streaks adjacent to Craney Island Disposal Site, Hampton Roads. Print enlargement from 70 mm transparency. Fixed (longer streaks) and mobile (shorter streaks) dye buoys. The cause of streaking for the mobile buoy plumes is not wind drag. Surface layer shear is indicated.

Middle Ground, and the northwest corner of the Craney Island Disposal Area be north of the 36°56'N latitude.

A full report of this study was prepared by Welch and Neilson (1976), and submitted to the consulting engineering firms of McGaughy, Marshall & MacMillan and Hazen & Sawyer, for ultimate presentation to the Hampton Roads Sanitation District Commission (HRSDC).

DECISION

The VIMS recommendation for the more northerly outfall site has been accepted by HRSDC. The Virginia State Health Department Bureau of Shellfish Sanitation also accepted the VIMS recommendation and communicated this recommendation by letter of 4 February (see Appendix) to the Division of Construction Grants, Virginia State Water Control Board.

A public hearing was held in mid-February by the Virginia Department of Health, Bureau of Shellfish Sanitation, with attendance by the Environmental Protection Agency (Philadelphia), the Food and Drug Administration, HRSDC, VIMS, and the Virginia State Water Control Board. The VIMS recommendation was accepted. The FDA has in general approved the entire project. Some details yet to be resolved concern the radius of the region around the outfall site that will be closed to shellfishing, a holding pond, and on-line safety features.

Thus, the VIMS recommendation for the more northerly outfall site based on remote sensing has been accepted, and the outfall will be built at this new location, in order to protect important shellfish beds.

Appendix B contains an illustrated presentation of the results of this study.

2. PIANKATANK RIVER POLLUTION MODEL DYE STUDY

THE PROBLEM

During the second week in October of 1975, the Department of Physical Oceanography at VIMS conducted a study of dispersion in the Piankatank River Estuary. The study involved the overboard release of 120 liters of Rhodamine dye and monitoring its dispersion through the river for ten days. The purpose was to provide data for a water pollution control mathematical model to be used by the Virginia State Water Control Board (SWCB).

USE OF REMOTE SENSING

Data were gathered in the traditional manner using a boat-borne fluorometer taking continuous readings along transects. Readings were recorded on a strip chart and dye concentrations were calculated using the chart and calibration data.

Specific locations were obtained in this study using prominent land features noted on the strip chart in the appropriate places. Since the boat travelled at a constant speed, it was possible to assign dye concentrations to locations between these points with reasonable accuracy.

Aerial photography was obtained to monitor the spread of dye more effectively in the initial stages, after release, and to obtain better determination of boat-track locations.

METHODS

Aerial photography was taken on October 15, 1975. This was the second day of the study when weather was excellent and the dye most visible. Photography was taken with a Hasselblad 500 EL/M camera with a 50 mm Distagon lens from an altitude of 1070 m using Kodak positive transparency high speed Ektachrome film. In order to coordinate with the ongoing fieldwork, an observer was on the boat in the river. Communications between aircraft and boat was via Citizen Band Radio using standard frequencies. With each photo run, the time was noted and that frame which centered the boat was recorded on the strip chart so that aerial photography could be matched to the appropriate position of the chart.

Photography was taken during one slack water run up the river and was identified by time and location. Dye was observed to be concentrated in the main channel of the Piankatank River. It was noted that the dye was more visible to the observer in the aircraft than was recorded on film.

Film densities were obtained using a Brumac Industries transmission densitometer with a 1 mm aperture. Dye concentrations were obtained from the strip chart at 30 second intervals. Corresponding image points (beyond the imaged boat position) were located via the scale of the photo and the speed of the boat. The boat wake through a dye patch and suspended sediment plumes made the aft-ward positions particularly obvious.

A template of the river was made using a Bausch & Lomb Zoom Transfer Scope, and positions at 30 second intervals from the original were drawn on the template. Three density readings across the main dye stream were obtained and their average taken. At boat positions, density readings were taken to either side of the boat so as to avoid an error caused by increased transmission through the boat's wake.

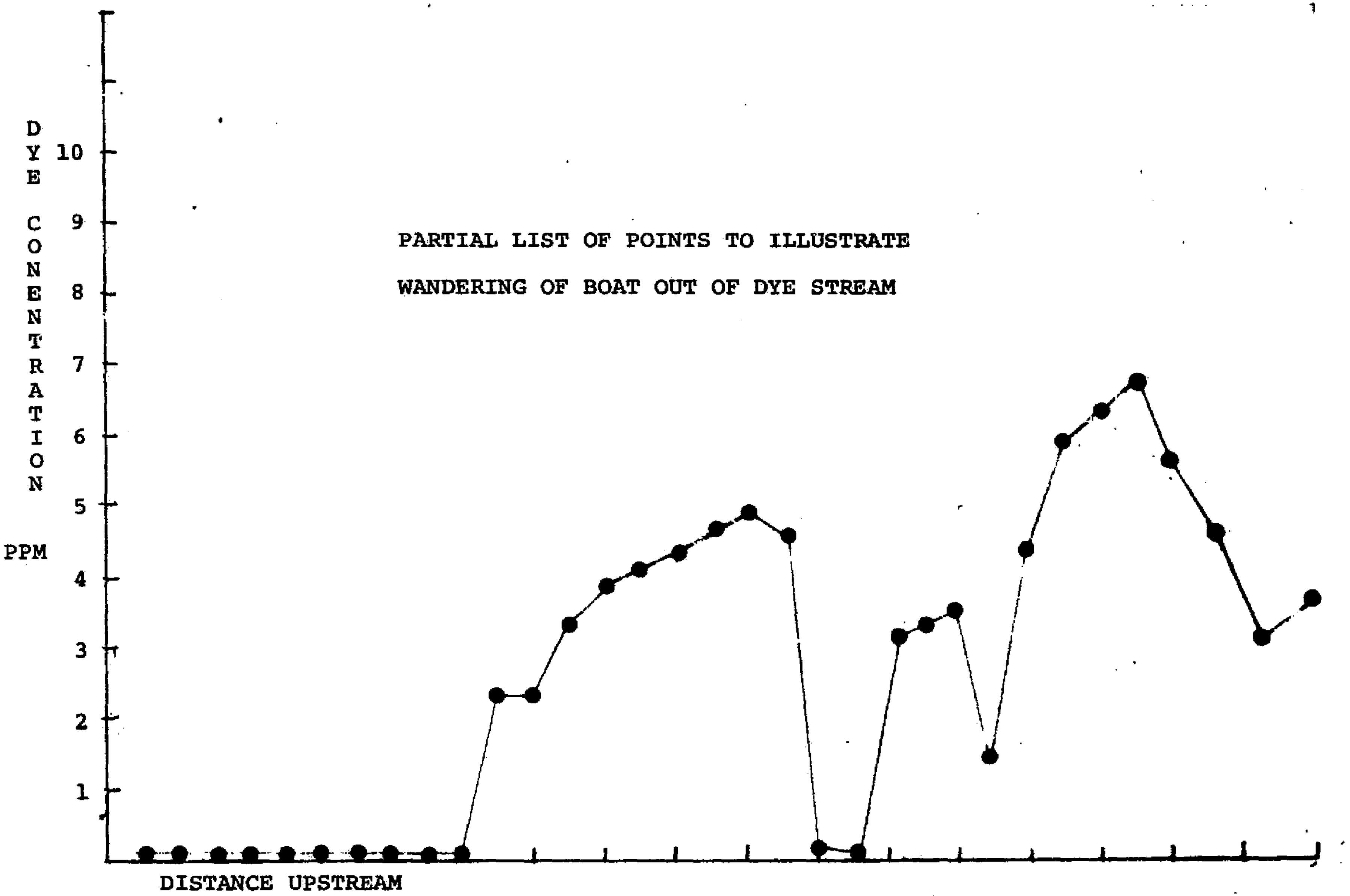
RESULTS

The straight boat transect left the dye patch several times due to the inability of the observers in the boat to see the elongate configuration of the patch. Observers in the plane were able to direct the boat back into the dye stream in several cases. However, there are many areas on the strip chart where a rapid decrease in dye concentration was observed. Photointerpretation and densitometric measurements prove that the boat transect left the curved dye patch. Figure 5 illustrates the effect of the curved dye patch on dye concentration measurements.

DISCUSSION

The effect of straight transects (if not accounted for) is to reduce the average level of dye detection, thereby producing erroneously high dispersion values. This error is confined to the initial days after release, because later, the dye is presumably more uniformly distributed in the cross-river direction.

Figure 5. Effect of Boat Wanderings on Measured Dye Concentrations.



DYE CONENTRATION
PPM
10
9
8
7
6
5
4
3
2
1
PARTIAL LIST OF POINTS TO ILLUSTRATE
WANDERING OF BOAT OUT OF DYE STREAM
DISTANCE UPSTREAM

Erroneously high dispersion values would lead the SWCB to permit greater than intended pollutant loading of the Piankatank River. The error can be reduced with remote sensing. Thus, the use of aerial photography to measure dye concentrations soon after release is an important complement to the fluoremetric technique.

DECISION

Those portions of the data affected by boat-track data-loss as illustrated in Figure 5 will not be included in the data reduction. The calculation of the dispersion coefficient will be based only on the envelope of high dye concentration readings. This procedure will insure the calculation of the most conservative value of the dispersion coefficient, and ultimately have the effect of reducing pollutant loading in the Piankatank River.

3. JACKSON RIVER FLOOD CONTROL PLANNING

THE PROBLEM

Flooding of the Jackson River at Covington, Virginia led Covington to request flood control by the U.S. Army Corps of Engineers, Norfolk, Virginia. As the means of flood control, the Army Corps proposed river bank modification along a 13 km stretch of the Jackson River above Covington. Because this would involve loss of trees, the Army Corps decided to compare the value of the trees against the value of flood control. Tree type, height, and vigor were necessary inputs to the decision making process.

THE CHOICE OF REMOTE SENSING

The nature of the mountainous terrain, the area to be covered, and personnel limitations on the part of the Corps made a complete ground assessment of the site prohibitive. Remote sensing with color infrared film offered a very convenient alternative way to map tree types, measure selected tree height using stereo photography, and assess relative vigor, all at a considerable savings in time and personnel.

METHODS

The Covington flight was performed on August 28, 1975 in the Cessna Cardinal using the Hasselblad 500 EL/M camera with the wide angle 50 mm lens. Photography was taken at a scalc of 1:12,000 using Kodak Plus X Panchromatic negative film and Kodak

Color Infrared Film 2443. Approximately 13 km of the Jackson River to the south and east of the town of Covington were imaged in eleven flight lines at an altitude of 609 m above the river. Photography was taken with overlap exceeding 50% to insure use in making stereo photogrammetric measurements.

RESULTS

Both the color infrared film and panchromatic negative film were processed by a professional laboratory. Duplicate positive transparencies were made for both, and the original products turned over to Mr. Robert Currie of the Army Corps of Engineers for interpretation and action.

A photomosaic of the area was made by the Corps and a vegetation survey performed. From this the economic value of the trees bordering the river was assessed. A decision whether or not to modify the stream borders is in abeyance because of recent program funding cutbacks within the Corps.

4. LITTLE CREEK AND LYNNHAVEN POLLUTION MODEL TIDAL PRISM

THE PROBLEM

A Little Creek, Lynnhaven model is being developed by the VIMS Department of Physical Oceanography and Remote Sensing Section to aid the Hampton Roads Water Quality Agency with the preservation of water quality in the lower Chesapeake Bay. The mathematical model will predict concentrations and flushing time of pollutants in small estuaries and coastal embayments. The model by Ketchum (1951), which describes the exchange between various parts of an estuary as a result of tidal oscillations, and which permits the calculation of the average distribution of fresh and salt water within the estuary, forms the theoretical basis for the equations. The Ketchum model is being modified to work for both conservative and nonconservative pollutants, and will be first applied to Little Creek and Lynnhaven Bays. Of particular interest will be the movement of water within a system between small bays and larger basins, and the residence time of materials released from various locations.

Lynnhaven and Little Creek Bays are located adjacent to one another, southwest of the mouth of Chesapeake Bay. The study sites consist of a complex network of larger basins and small bays interconnected by channels, with a moderate amount of marsh. The area is heavily developed with industry and single family residences. Little Creek in particular is the site of a large naval base with a high volume of ship traffic. The resulting model will offer an excellent opportunity to determine the effect and fate of non-point source pollution which has been a problem in these two systems.

THE CHOICE OF REMOTE SENSING

Necessary inputs to the model include the low tide volume of water in the estuary, the high tide volume, and the local intertidal volume (the fraction of the total tidal prism in each part of the estuary at high tide). It is important for the modified Ketchum model to have high accuracy in these inputs since the estuary is divided into segments which represent the excursion of a wat r particle during a tidal cycle. This is done by requiring that the low tide volume of each segment be equal to the high tide volume of the next landward segment.

Low tide and high tide volumes can be calculated grossly from mean tidal range and topography, and consequently an estimate of tidal prism can be made. However, low accuracy results from the fact that shoreline topography is not well-known.

In contrast, if an accurate measurement of water surface area is available, and tide gauges are installed in the system, the total tidal prism can be calculated, and intertidal volumes much more accurately determined.

Remote sensing with black and white infrared film shows an excellent land-water interface, and has been used successfully for resolving the time dependant storage function for an inlet-marsh-bay system (Gordon, Penney and Byrne, 1973). The film can be used with conventional mapping equipment to make water surface maps at various tidal stages. The availability and accuracy of this method, coupled with the absence of any acceptable alternative, led to its adoption.

METHODS

The procedure is to image the area of interest during a rising or falling tide at regular intervals. The nature of B & W IR film with a very deep red filter (Wratten 25a) is to record only near infrared energy. Since water reflects very little energy in the infrared, whereas land has a relatively high reflectance, the land-water contrast is good. The advancing water can be easily discerned as it covers the lower land features, and the total area-time relationship determined.

Both bays were overflown five times on October 5, 1975 during a half-tidal cycle. Little Creek was imaged with one flight line, and Lynnhaven with five lines from an altitude of 1830 m (6,000 ft) using a Hasselblad 500 EL/M camera with a 50 mm wide angle lens, resulting in a nominal scale of 1:36,000. Approximately 350 frames of Kodak 2424 High Speed Black and White Infrared film were exposed and processed to a black and white negative. A contact print of all the imagery was then made to form the working 70 mm positive transparency. The duplicate was cut by flight line, conjugate areas removed, and the frames re-joined to form contiguous, non-overlap coverage. In essence, this method produced an uncontrolled mosaic. An example of a single flight line for Little Creek is included as Figure 6. Note that water is black indicating low reflectance, and land features are white, making the land/water interface unambiguous.

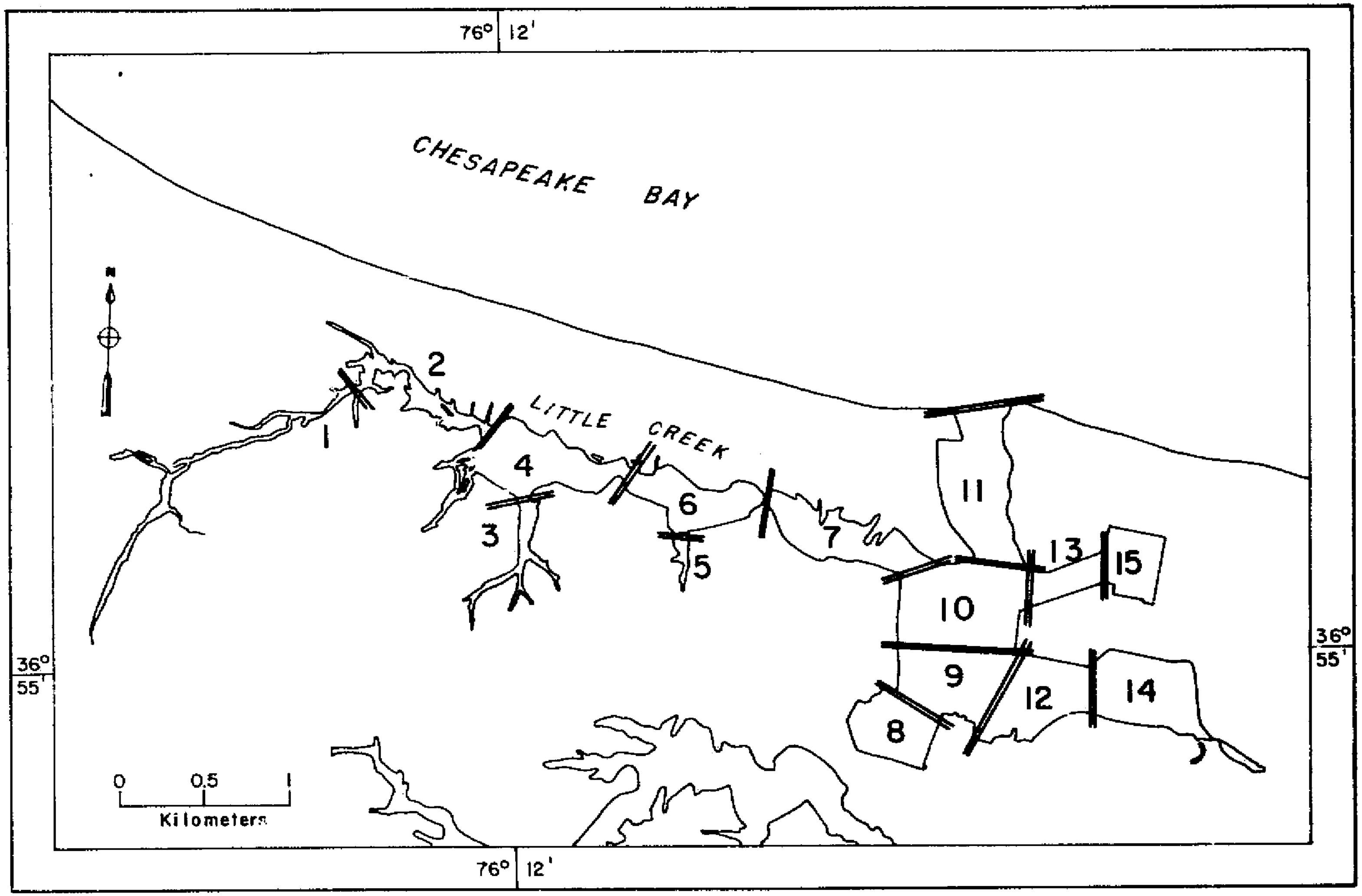
The next step was to make an accurate map of both systems to calculate the water area at high tide. The mathematical model

Figure 6. Black and white infrared photomosaic of Little Creek. Original scale 1:36,000, bar on photomosaic at bottom left represents 1000 m. Darkest tones represent water, bordering grey areas marsh, and lightest tones land. United States Naval Amphibious base occupies the eastern end of Little Creek.


N

based on the model by Ketchum for estuaries with a fresh water input and tidal oscillations, necessitates the division of the basin into segments of relatively uniform topography. Maps of Little Creek and Lynnhaven (Figures 7 and 8) illustrate the major segments (sections) chosen. Within Lynnhaven, segments were further subdivided where necessary to increase mapping accuracy by minimizing the distortions due to camera tip and tilt, and enabling a series of larger scale maps to be drawn. A Bausch and Lomb Zoom Transfer Scope was used to rectify and scale adjust the imagery to a 1:24,000 USGS topographic map using prominent nonchanging features. A simple change of map lenses was then made to allow an enlargement to be drawn at approximately 4 times the topographic scale (1:6,900). This step was necessary to produce areas large enough for accurate planimetry of the many small creeks and bays comprising the system. Fifteen maps were drawn for Little Creek and more than 50 for Lynnhaven, each separately scaled. The enlarged base maps were then planimetered, using an electronic coordinate digitizer at NASA Langley Research Center and numerical integration performed by computer, to calculate the area of each segment. The area of marsh islands within each segment was measured and subtracted from the basin area to arrive at the high tide water area. The low tide area was then calculated by drawing in the exposed mud flats, shoals, and beaches on the base maps and subtracting these from the high tide area. The measurements are included in Tables 2 and 4, and the calculated area changes in Tables 3 and 5.

Figure 7. Map of Little Creek showing segments.



76° 12'
CHESAPEAKE BAY
LITTLE CREEK
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
N
36° 55'
0 0.5 1
Kilometers

Figure 8. Map of Lynnhaven showing segments and subsegments.

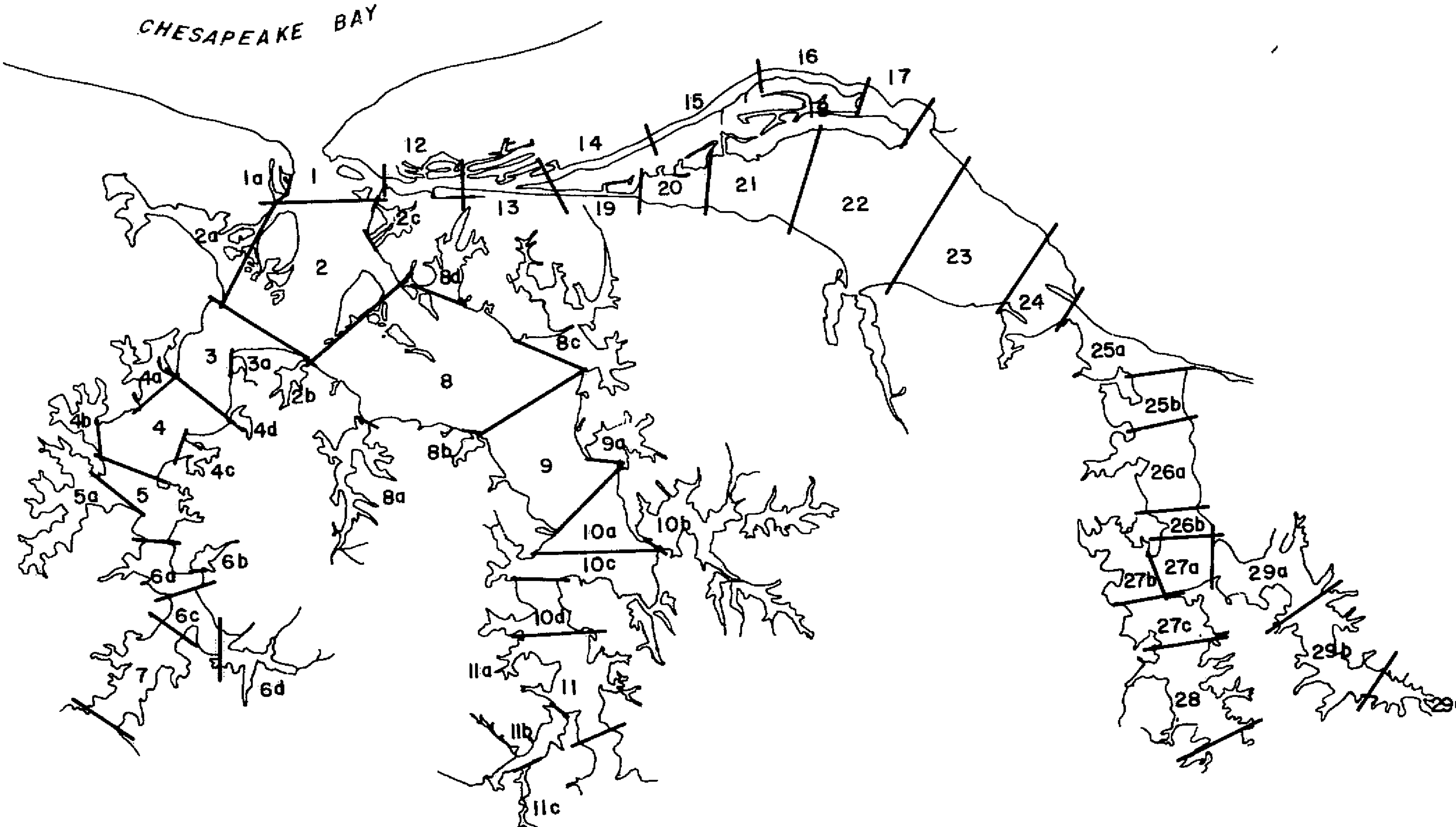

CHESAPEAKE BAY
1a
1
2a
2
2b
2c
3
3a
4
4a
4b
4c
4d
5
5a
6a
6b
6c
6d
7
8
8a
8b
8c
8d
9
9a
10a
10b
10c
10d
11
11a
11b
11c
12
13
14
15
16
17
18
19
20
21
22
23
24
25a
25b
26a
26b
27a
27b
27c
28
29a
29b
29c

TABLE 2 . Little Creek Water Surface Area (10^3 square feet)*

Section	Basin Area	Marsh Area	Low Tide Bar Area
1	1,240	381	--
2	1,100	44	10
3	634	87	--
4	2,940	148	19
5	186	14	--
6	2,070	---	7
7	2,310	---	27
8	1,930	---	--
9	2,450	---	--
10	4,110	---	--
11	3,500	---	68
12	2,680	---	--
13	961	---	--
14	2,570	---	--
15	1,430	---	--

* English units were used to satisfy users.

TABLE 3. Little Creek Water Surface Area Change

Section	High Water Area (ft^2)	Low Water Area (ft^2)	% Change
1	859,000	859,000	---
2	1,056,000	1,046,000	0.9
3	547,000	547,000	---
4	2,792,000	2,773,000	0.7
5	172,000	172,000	---
6	2,070,000	2,063,000	0.3
7	2,310,000	2,283,000	1.2
8	1,930,000	1,930,000	---
9	2,450,000	2,450,000	---
10	4,110,000	4,110,000	---
11	3,500,000	3,432,000	1.9
12	2,680,000	2,680,000	---
13	961,000	961,000	---
14	2,570,000	2,570,000	---
15	1,430,000	1,430,000	---

TABLE 4 . Lynnhaven Inlet Water Surface Area (10^3 square feet)

Section	Sub-section	Basin Area	Marsh Area	Low Tide Bar Area
1	-	3,300*	255	26.19
1	A	179.3	-	54.2
1 TOTAL		3,509	255	80
2	-	14,000*	3,305.23	2,187.05
2	A	4,080	354.97	129.30
2	B	592	-	-
2	C	590.3	91.62	51.63
2 TOTAL		19,262	3,752	2,368
3	-	4,360	-	289.09
3	A	335	-	-
3 TOTAL		4,695		289
4	-	5,400*	-	-
4	A	1,450	-	-
4	B	1,450	-	-
4	C	436	-	-
4	D	218	-	-
4 TOTAL		8,954		
5	-	2,962*	-	-
5	A	3,910	-	-
5 TOTAL		6,812		
6	A	2,070	-	-
6	B	366	-	-
6	C	1,670	-	-
6	D	1,480	13.8	8.97
6 TOTAL		5,586	14	9
7	-	3,930	-	22.02
7 TOTAL		3,930		22
8	-	18,700*	813.3	51.7
8	A	2,290	-	?
8	B	429.4	-	?
8	C	4,320	-	42.43
8	D	1,611.2	49.7	45.84
8 TOTAL		27,351	862	140
9	-	8,350*	-	-
9	A	1,440	20.98	155.1
9 TOTAL		9,790	21	155

* Area measured from USGS 7.5' topographic map

Table 4, Cont'd.

Section	Sub-section	Basin Area	Marsh Area	Low Tide Bar Area
10	A	2,820	-	-
10	B	3,227	-	251.9
10	C	4,730	-	89.4
10	D	2,340	-	104.6
10 TOTAL		13,117		446
11	-	4,340	77.44	10.4
11	A	493	-	16.5
11	B	1,315	53	-
11	C	376	90.05	-
11 TOTAL		6,524	220	27
12	-	1,360	-	-
12 TOTAL		1,360		
13	-	1,640	12.8	12.3
13 TOTAL		1,640	13	12
14	-	857	-	-
14 TOTAL		857		
15	-	1,180*	-	-
15 TOTAL		1,180		
16	-	811*	-	-
16 TOTAL		811		
17	-	1,230	-	-
17 TOTAL		1,230		
18	-	539	-	-
18 TOTAL		539		
19	-	720	-	-
19 TOTAL		720		
20		2,020	-	-
20 TOTAL		2,020		
21	-	5,370*	-	-
21	A	235	-	-
21 TOTAL		5,605		
22	-	14,300*	-	-
22	A	786	-	-
22 TOTAL		15,086		

* Area measured from USGS 7.5' topographic map

Table 4, Cont'd.

Section	Sub-section	Water Area	Marsh Area	Low Tide Bar Area
23	-	9,290*	-	-
23 TOTAL		9,290		
24	-	3,480	-	-
24 TOTAL		3,480		
25	A	3,030	-	-
25	B	3,000	-	-
25 TOTAL		6,030		
26	A	4,470	-	-
26	B	1,300	-	-
26 TOTAL		5,770		
27	A	2,120	-	-
27	B	3,290	-	-
27	C	3,000	-	-
27		8,410		
28	-	4,440	-	-
28 TOTAL		4,440		
29	A	4,280	-	-
29	B	3,950	-	-
29	C	1,410	165	-
29 TOTAL		9,640	165	

* Area measured from USGS 7.5' topographic map

TABLE 5 . Lynnhaven Inlet Water Surface Area Change

Section	High Water Area (ft^2)	Low Water Area (ft^2)	% Change*
1	3,254,000	3,174,000	2.5
2	15,510,000	13,142,000	15.3
3	4,695,000	4,406,000	6.2
4	8,954,000	8,954,000	-
5	6,872,000	6,872,000	
6	5,572,000	5,563,000	0
7	3,930,000	3,908,000	0.6
8	26,489,000	26,349,000	0.5
9	9,769,000	9,614,000	1.6
10	13,117,000	12,671,000	3.4
11	6,304,000	6,277,000	0.4
12	1,360,000	1,360,000	-
13	1,627,000	1,615,000	0.7
14	857,000	857,000	-
15	1,180,000	1,180,000	-
16	811,000	811,000	-
17	1,230,000	1,230,000	-
18	539,000	539,000	-
19	720,000	720,000	-
20	2,020,000	2,020,000	-
21	5,605,000	5,605,000	-
22	15,086,000	15,086,000	-
23	9,290,000	9,290,000	-
24	3,480,000	3,480,000	-
25	6,030,000	6,030,000	-
26	5,770,000	5,770,000	-
27	8,410,000	8,410,000	-
28	4,440,000	4,440,000	-
29	1,245,000 9,475,000	1,245,000 9,475,000	-

$$* \quad \frac{\text{High Water - Low Water}}{\text{High Water}} \times 100$$

ERROR ANALYSIS

Two sources of error which exist in the area measurement process were examined. The first is from scaling imagery to a base map, and removing (minimizing) apparent differential scale changes due to camera tip and tilt. The second source of error is in the planimetry.

Imagery with a small amount of distortion from tip and tilt can be successfully adjusted to fit a base map by simple scale adjustment. In this study a Bausch and Lomb Zoom Transfer Scope was used and each small segment of the complex study area was scaled to a USGS 7.5 minute topographic map. Common features apparent both in the imagery and map such as roads, housing developments, and larger buildings were used. Each time a new segment or subsegment was scaled from the imagery to the topographic sheet and drawn at a fixed magnification, a new scale factor was calculated for the drawing. The Lynnhaven study area comprised more than 50 small segments and subsegments, and the Little Creek area included 15 segments. The mean scale for all maps drawn was 1:6,840, with standard deviation of 0.8% of the mean.

In order to check the accuracy of the planimetry three concentric circles were drawn and diameters carefully measured to 0.001 inch with a microrule. The digitizing process approximates the circles with a series of short lines drawn between (x, y) points. Numerical integration is then done by computer to calculate the enclosed area. A circle, then, should represent the limiting case for accuracy. Results of the planimetered and calculated areas agree to within 0.5%, averaged for the three circles. Figure 9 shows Little Creek segment 2a as originally drawn (a) and a computer plot made by connecting digitized x, y pairs with short straight lines (b). The numerical integration is performed using the x, y coordinate pairs in a computer program.

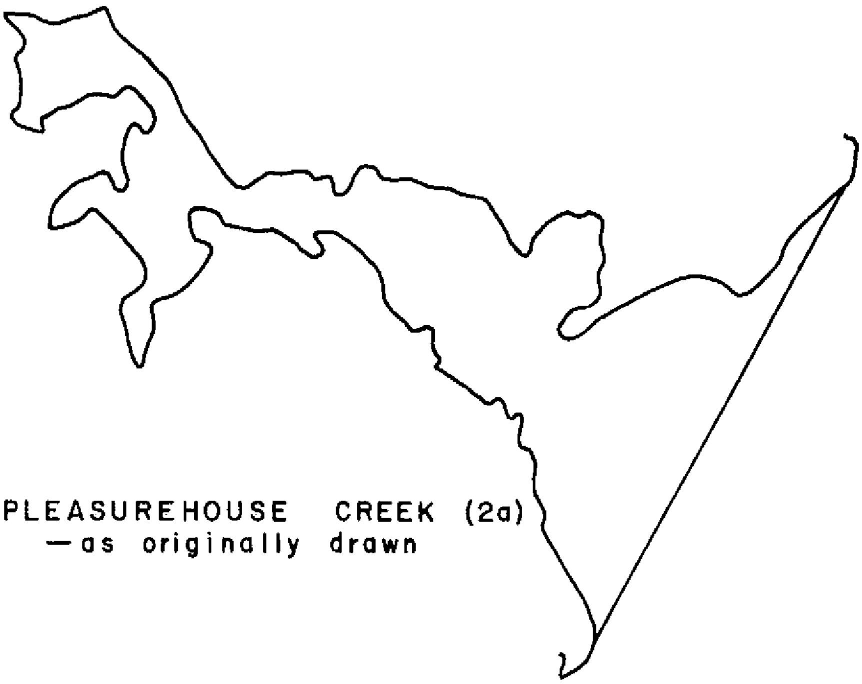
It is concluded that careful application of the scaling techniques and computer digital planimetry result in area measurements accurate to approximately 2% and consistent to 1% or less.

RESULTS

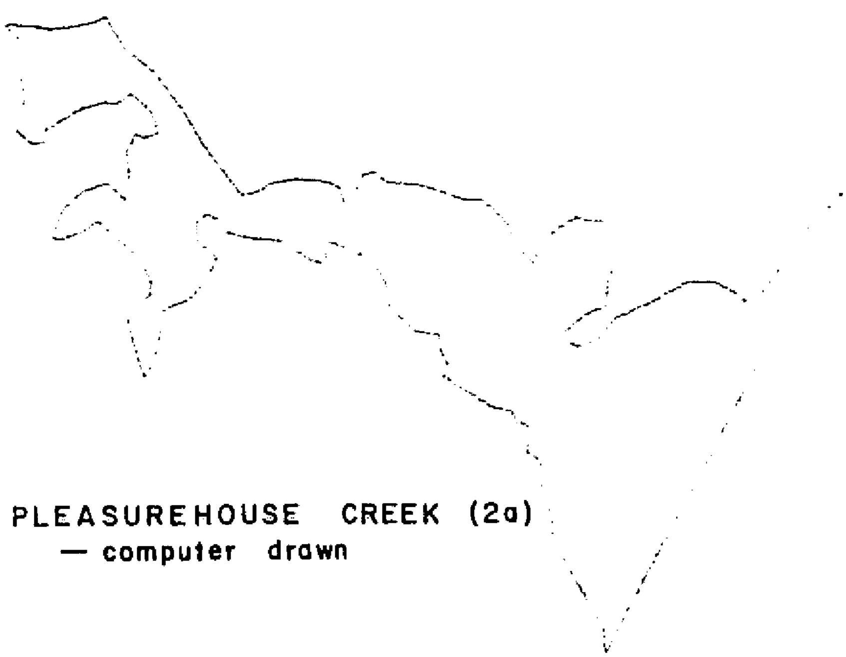
The remote sensing phase of this project is finished, and has defined those areas where the local tidal prism results in depth change with little area change, and those places where depth and area change simultaneously. These data are to be incorporated directly into the model, and as discussed have provided justification for use of the model.

The model is scheduled to be completed by the end of 1976 and will be used by the Hampton Roads Water Quality Agency. Output from the model will form a basis for the management of the Little Creek and Lynnhaven systems by the State Water Control Board regarding industrial and residential loading.

Figure 9. Little Creek segment 2a as originally drawn and as drawn by computer.



a. PLEASUREHOUSE CREEK (2a)
— as originally drawn



b. PLEASUREHOUSE CREEK (2a)
— computer drawn

5. ISLE OF WIGHT NON-POINT POLLUTION MODEL TIDAL PRISM

THE PROBLEM

The Maryland Department of Natural Resources has contracted with The Department of Physical Oceanography at VIMS to collect input data for a storm runoff (non-point) pollution model. VIMS has chosen a small salt marsh in southern Maryland, north of Isle of Wight Bay, close to Ocean City (see Figure 10), to collect data on marsh water run-off and nutrient mass fluxes. The study is similar to the Lynnhaven-Little Creek study described elsewhere in this document, although the physiography of the area is much simpler and there are no existing sources of industrial or residential waste. A mathematical model of the system is desired as a product describing the response of the marsh to tide and fresh water input from rain. The amount of water stored in the system as a function of tide, as well as the distribution in area, must be known to establish a baseline picture of system response.

Maryland will contract for the development of the model itself in 1977. The model will be used in making land-use decisions by providing quantitative data on water quality impacts due to proposed land-use changes.

USE OF REMOTE SENSING

The distribution and volume of water in the marsh system can be determined quickly and cheaply using panchromatic infrared film and sequential vertical aerial photography. This method was chosen over a current meter method because all potential marsh inputs and exist were monitored, and the time required for installation and maintenance of current meters was eliminated. Also, some shallow channels would not allow use of current meters.

METHODS

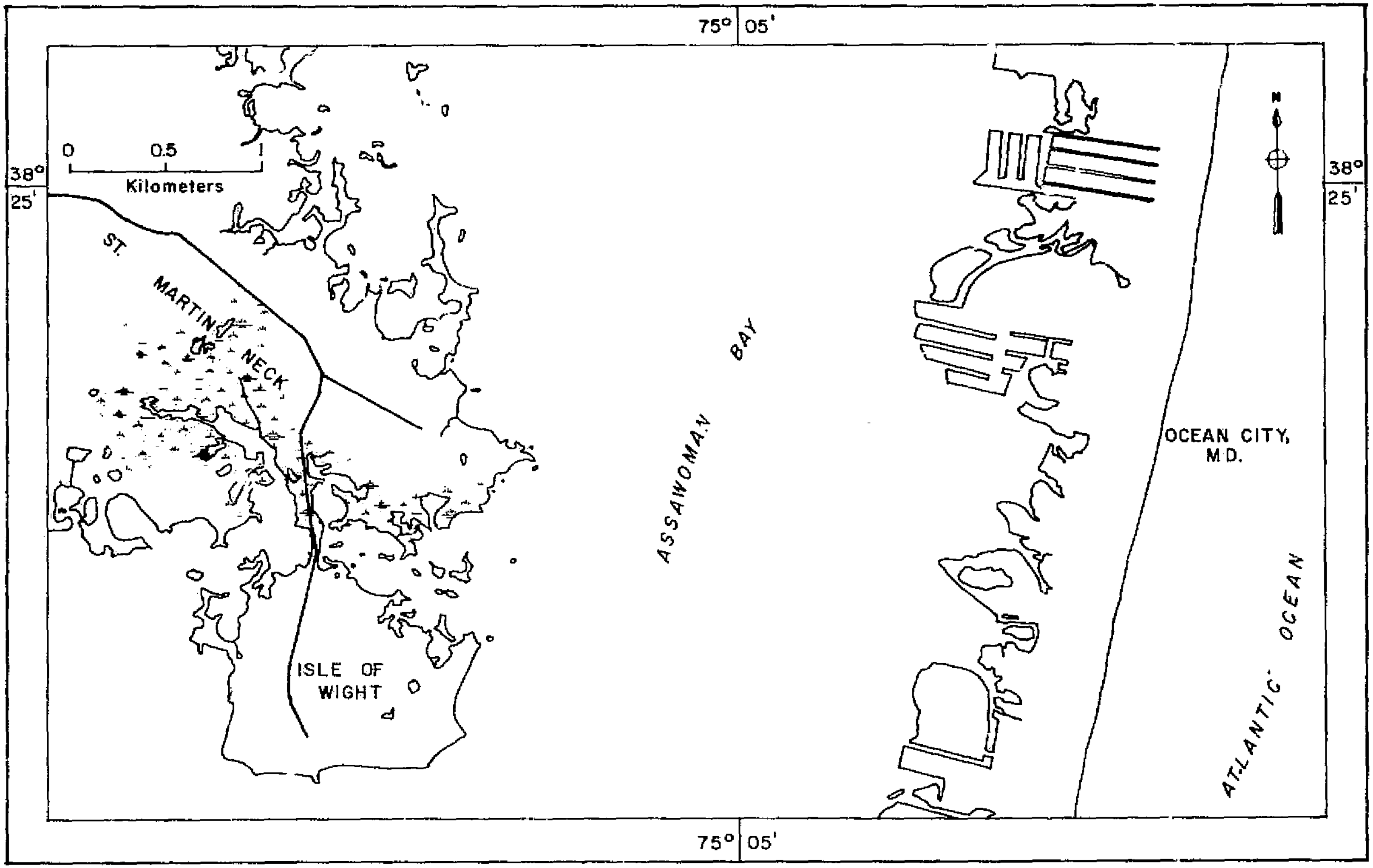
The remote sensing method used is described in Gordon, Penney, and Byrne (1973), and consisted of panchromatic infrared film coverage at intervals throughout a rising half-tidal cycle.

RESULTS

The aerial photography was acquired on November 28, 1975 using the Hasselblad 500 EL/M camera and a wide angle lens. Despite a light leak during some phase of handling before exposure or at processing time, which degraded the quality of the imagery, land-water boundaries could still be discriminated. Area measurements made by the same technique as in the previous chapter indicate no change throughout the tide cycle within the marsh. Changes which should have occurred with semi-diurnal tide were apparently masked by the wind generated tide, and the system remained essentially static.

New photography will therefore need to be obtained again under no wind conditions before the area-height relationship can be determined. The marsh and other data will not be communicated to the State of Maryland until later in 1976.

Figure 10. Isle of Wight, Assawoman Bay, Maryland.


75° 05'
38° 25'
0 0.5 1
Kilometers
ST. MARTIN NECK
ASSAWOMAN BAY
ISLE OF WIGHT
OCEAN CITY, M.D.
ATLANTIC OCEAN
N

6. CEDAR LANDING ESTATES WETLANDS DESTRUCTION

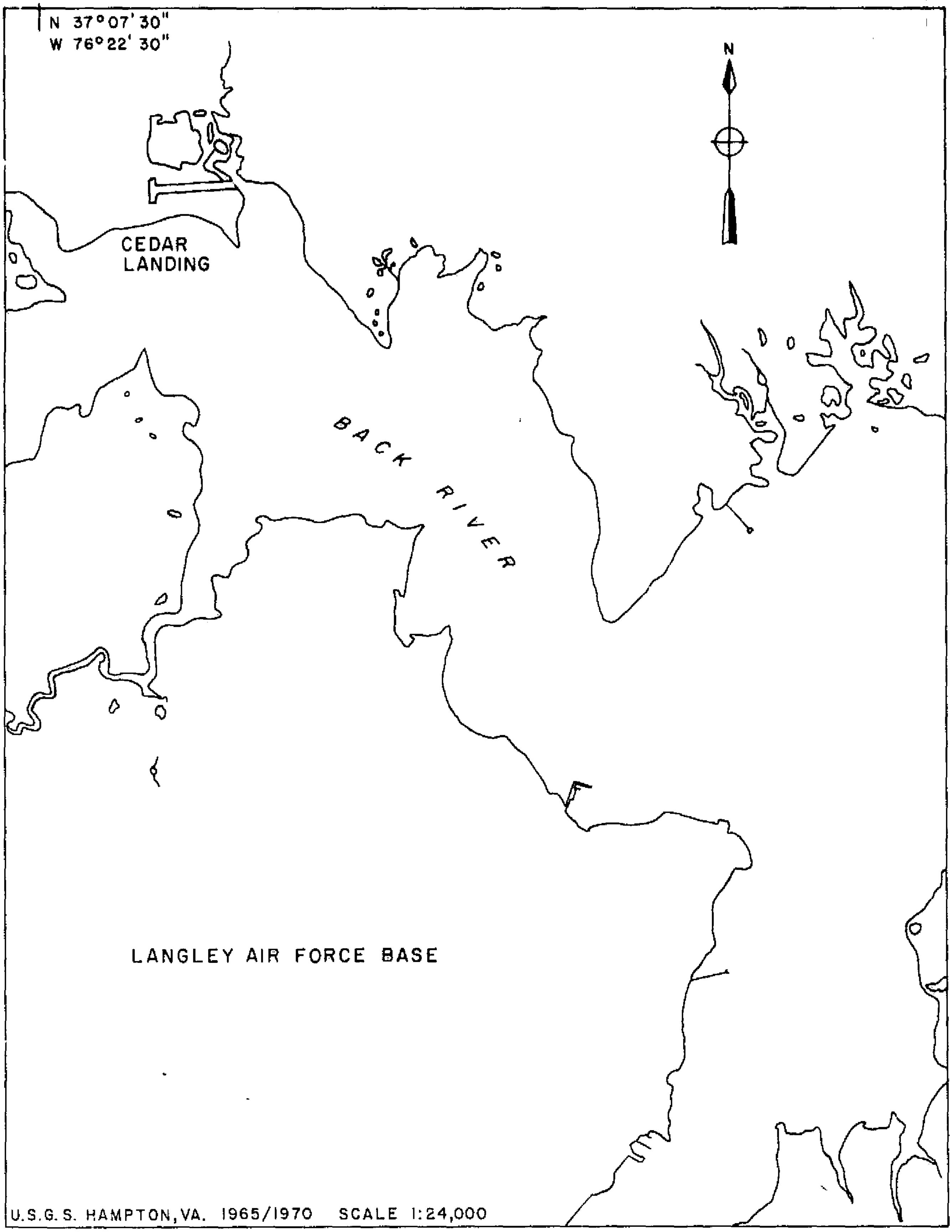
THE PROBLEM

Modification of Virginia wetlands has come under strict control since passage of the Virginia Wetlands Act (1972) by the General Assembly, Commonwealth of Virginia. Despoilers also face the law against unauthorized alteration of navigable waterways (1899) enforced by the U.S. Army Corps of Engineers. The Corps plus other federal agencies and Virginia state agencies have energetically exercised permit regulation and vigorously pursued violators operating without permits.

In mid-July 1975 the Corps decided to investigate a residential construction and development project, Cedar Landing Estates, at Cedar Landing, in Poquoson, Virginia, a northern shorepoint of the Back River across from Langley Air Force Base (see Figure 11). This project has proceeded over several years with the filling of wetlands, the dredging of drainage channels, and the creation of new waterways. Houses and boat facilities have been constructed. No permit was ever sought by the developer from the Corps for the activities involving the waterways.

The Corps began to collect data on the project history, and asked VIMS for assistance in compiling a photographic history. The questions to be answered were what specific waterway alterations were made by the developer, and when did they occur.

Figure 11. Cedar Landing, Poquoson, Virginia.


N 37°07'30"
W 76°22'30"
N
CEDAR
LANDING
BACK RIVER
LANGLEY AIR FORCE BASE
U.S.G.S. HAMPTON, VA. 1965/1970 SCALE 1:24,000

APPLICATION OF REMOTE SENSING

A photographic history of the area was sought because it is an excellent source of information during an investigation, and because it can be used as evidence for prosecution. Precisely dated aerial photography allows development activities to be chronologically arranged with certainty. During the preliminary data gathering by the Corps, the question arose as to when a lagoon dredged out by the developer was made hydrodynamically contiguous with the Back River. A widening years ago of a previously existing drainage channel would escape prosecution, by expiration under statutes of limitation. VIMS and the Corps agreed that photo interpretation could pinpoint the time when the lagoon opening was established and/or enlarged.

METHODS

A search of the VIMS photo library yielded a list of 6 dates of aerial photography between 1953 and 1973. This imagery plus new 1975 imagery (see Table 6) includes NASA high altitude color infrared imagery, U.S. Department of Agriculture photography, and VIMS low altitude nadir and oblique color photography. The imagery was examined by enlargement, with particular attention to water color details.

RESULTS

Copies of the imagery in 35 mm format were sent to the Corps. Availability of the NASA imagery at the EROS Data Center

Table 6

AERIAL PHOTOGRAPHY OF CEDAR LANDING, BACK RIVER,
POQUOSON, YORK COUNTY

1953 - U.S. Department of Agriculture
Production and Marketing Administration
Symbol DWI, PMA 28-54 DC; Item No. 1; Scale 1:20,000
10-31-53 (date). DWI-4N-46 (frame number).
See photo index of York County, Virginia copies 1-13-54 (flying completed 12-17-53), Woltz Studios, Des Moines, Iowa.
Panchromatic, 9-in. format, 6-in. lens.

1963 - Commonwealth of Virginia, Department of Highways.
Scale 1:16,800
February 22, 1963; 5-114-116-045 (frame number). See photo index of James City County, York County, Newport News and Hampton.
Panchromatic, 9-in. format, 6-in. lens.

1968 - NASA
(for details contact John Ruzecki at VIMS)
Panchromatic, 9-in. format, 6-in. lens.

1971 - NASA Houston
Mission 187, Site 224 James River Estuary, Virginia
October 12, 1971; 28-6294 (frame number).
Color infrared, 9-in. format, 6-in. lens.
Film 2443, Camera RC-8 #2.
Site 224, Flight 9, Altitude 24,600, Aircraft NC130B.

1972 - NASA Houston
Mission 207, Site 244 Central Atlantic Coastal Area
July 23, 1972; 48-0157
Color infrared, 9-in. format, 6-in. lens.
Film 2443, Camera RC-8 #1
Site 244, Flights 13-14, Altitude , Aircraft

1973 - VIMS
Shoreline Situation Reports
Department of Geological Oceanography
April 30, 1973; frame YK-1-14-114 and others
Low-altitude obliques
Color, 35 mm format.

1975 - VIMS
NASA grant
Department of Geological Oceanography
October 22, 1975. Color, 70 mm format

U.S. Geological Survey topographic sheet for Hampton, Virginia, SE/4 Hampton 15' Quadrangle N3700-W7615/7.5, 1965, photo revised 1970. Shows the boat haven and its opening to Back River as a photorevision based on aerial photographs taken 1970.

Compiler: JCM
Date: 15 Sep 75

was verified, and procurement data communicated to the Corps. The slides sent to the Corps were exposed at VIMS (and processed commercially by Kodak) from copies held by VIMS of the original USDA and NASA photography. The original USDA and NASA images would be best for showing small spatial details and color differences. Nevertheless, features appearing in the slides are visible in the original images, as photographic copying is simply a transfer process which, except for gross mishandling, will not introduce any new features. Consequently, features seen in the slides are reliable indicators of features to be seen on the original images, and of features of the water and terrain at the time of photography.

As to the question whether the T-shaped lagoon was open to the Back River at the time of NASA photography in 1971 and 1972, allowing free exchange of waters and water-borne inclusions between the lagoon and Back River, there are distinct color contrasts in both 1971 and 1972 images between the lagoon and Back River. The lagoon is a bright aqua, compared to a dark blue in Back River. Bright aqua on color infrared film signifies high suspended sediment levels in the lagoon. These color contrasts are convincing evidence that a barrier existed and that free exchange was prohibited. Confirming this conclusion, the highly reflective shoreline appears to extend completely across the end of the lagoon (base of the T) nearest the Back River. Of course, it is possible for a small channel to have existed between the lagoon and Back River which allowed a minimal exchange perhaps at high tide, for example, but there certainly is no indication of a free exchange.

In contrast, the 1973 35 mm photography by VIMS, carried out as part of its shoreline monitoring program, clearly shows similar water colors in the lagoon and Back River, and a large opening in the shoreline at the end of the lagoon. In conclusion, between 23 July 1972 and 30 April 1973, a large opening was established at the end of the lagoon permitting free exchange of water between the lagoon and Back River.

On 22 October 1975, additional incidental photography of the area was carried out by VIMS in 70 mm color format. From visual observations during the photographic overpass and from the imagery, it appears that new channels have been dug since 1973 which are capable of passing small power boats.

Figure 12 shows the changes which have occurred at Cedar Landing between 1953 and 1975.

ACTION

The information transmitted to the Corps was combined with other data assembled by the Corps. A litigation report containing maps based on photo-interpretation was prepared and was submitted by the Corps Office of Counsel to the U.S. Department of Justice.

Legal and political developments are in progress at the present time.

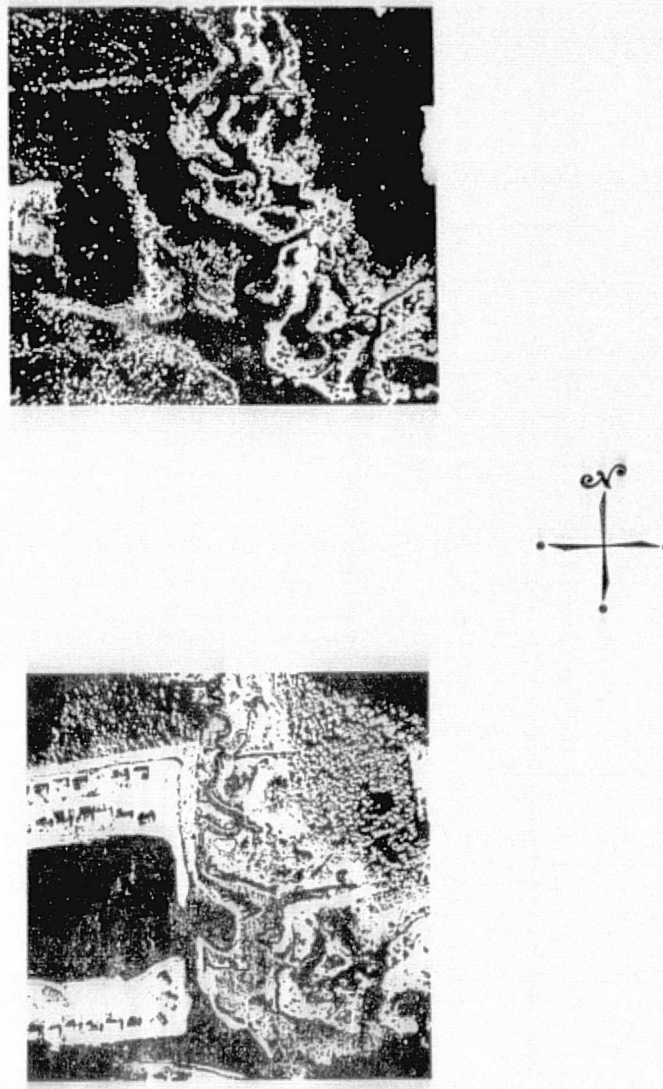


Figure 12 . Changes at Cedar Landing from 1953 to 1975.
Top: portion of U.S.D.A. image, 31 Oct. 53, DWI-4N-46.
Bottom: VIMS 70 mm image 22 Oct. 75.

BENEFITS, SAVINGS, AND COSTS

Table 7 shows that VIMS costs totaled $2620 (this figure includes a 100% surcharge for methods development). This grant bore the VIMS costs. All but the 1975 photography was an expense of earlier contracts and cost this project nothing.

Without the NASA high-altitude coverage, essential pieces of Cedar Landing history would have been missing. In fact, prosecution would have been very difficult if not impossible.

Successful prosecution may mean a recovery of several thousands of dollars in fines.

TABLE 7

COSTS, CEDAR LANDING ESTATES PROJECT

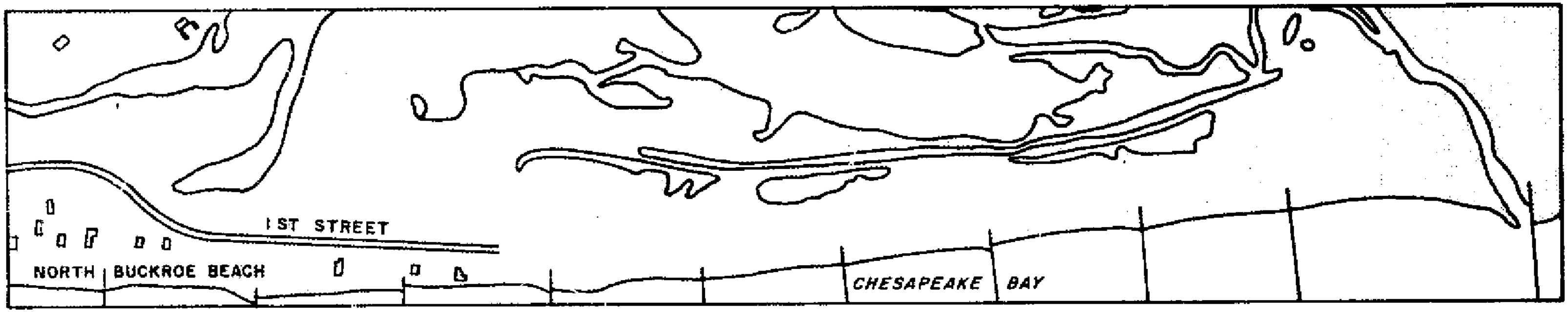
Salaries, Overhead, Fringe	
10 man-days @ $120/day	$ 1200
Aircraft Rental	
1 hour @ $35/hour	35
Film, Processing, Duplication	75
	$ 1310
Methods Development @ 100%	1310
	$ 2620

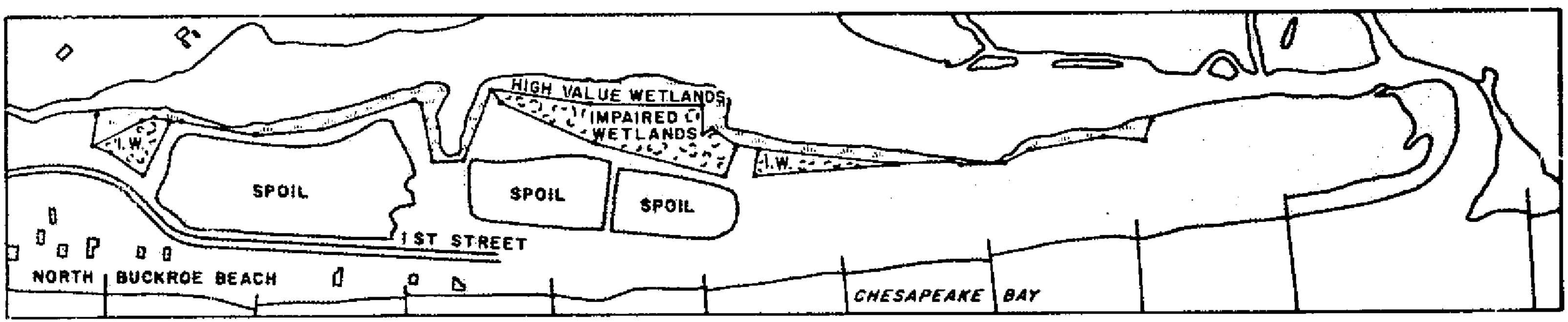
7. HAMPTON SALT PONDS WETLANDS PROTECTION AND INLET STABILIZATION

THE PROBLEM

In 1968, the City of Hampton began residential and recreational development of the Salt Ponds marshes, the City's largest wetlands area, containing 224 acres. Extensive unauthorized dredging destroyed tens of acres of marsh, and continued until late 1974 when the U.S. Army Corps of Engineers under new regulations issued a cease and desist order. The City then applied to the Corps and the Virginia Marine Resources Commission for a permit to complete the project. In its normal review procedure, VMRC asked VIMS to evaluate the environmental impact of the proposal and make recommendations. Two maps of the area, before and after changes were made without permit subsequent to 1969, are shown in Figure 13. The small inlet to the Chesapeake Bay which was dredged open is now stable, but not navigable by larger watercraft. The city is contemplating further dredging operations prior to releasing the land to a private developer to build a marina, condominiums, and single family dwellings. The city will not have a part in the development, but will prepare the land and will restrict the land use within general guidelines. Under recent Virginia wetlands law and existing Army Corps of Engineers regulations, a formal application must be submitted for any further dredging and stabilization structures for the inlet. Previous dredging has already resulted in damage and destruction of extensive wetlands, as assessed by VIMS wetlands ecologists.

Figure 13. Changes at Salt Ponds, Hampton, Virginia from 1969 to 1975.


1 ST STREET
NORTH BUCKROE BEACH
CHESAPEAKE BAY


HIGH VALUE WETLANDS
IMPAIRED WETLANDS
I.W.
I.W.
SPOIL
SPOIL
SPOIL
1 ST STREET
NORTH BUCKROE BEACH
CHESAPEAKE BAY

METHODS

In order to measure dredging effects and prepare recommendations an accurate base map of the area was necessary. Rather than employ a commercial mapping firm for this work, it was decided, since the capability now exists within VIMS in Remote Sensing for mapping, that the entire project could be handled faster and more expediently within one institution. VIMS personnel made a field survey of the marsh, staking the most valuable areas and sections of damaged marsh with white panels. VIMS subsequently overflew the salt ponds to image the marsh and the inlet, and to make an accurate and timely base map of the entire area on which to base all future modifications and development. Measurements of water and marsh area were made from the imagery-derived map to calculate the tidal prism. Finally, VIMS utilized imagery in preparing recommendations for jettys (see letter to Ashley in Appendix) to insure a stable, navigable access to the proposed and existing interior development.

Mapping imagery was acquired with color and color infrared film using the 70 mm Hasselblad 500 EL/M camera and wide angle lens. Mapping was performed on a Bausch & Lomb Zoom Transfer Scope using a 1968 USGS planimetric map (1:24,000) as a base. Accuracy was checked using a 1:1,200 survey map (prepared at an earlier date by a commercial firm) with markers which were visible in the aerial imagery. Results indicate agreement to approximately 1%. The 70 mm frames were rephotographed onto 35 mm , and photomosaics were made from both color and color infrared representations (Figures 14 and 15) to aid the city planners in the broad overview of the area, and to delineate the more vigorous marsh communities.

RESULTS

All measurements were made from the map based on imagery. The areas of remaining valuable marsh were delineated on maps (see Figure 13) for planners to avoid in future dredging and placement of spoil. Suggestions were prepared for inlet stabilization, in order to keep the channel navigable (see letter to Ashley in Appendix). Written recommendations along with maps, overlay, and photomosaics were presented to the City of Hampton.

Remote sensing has thus been used as a basis for recommended future work in the area. It was used to delineate the marsh boundaries, to facilitate tidal prism measurement for elucidating inlet behavior, and to give the Hampton planners and managers an up-to-date map and photo mosaic of the area.

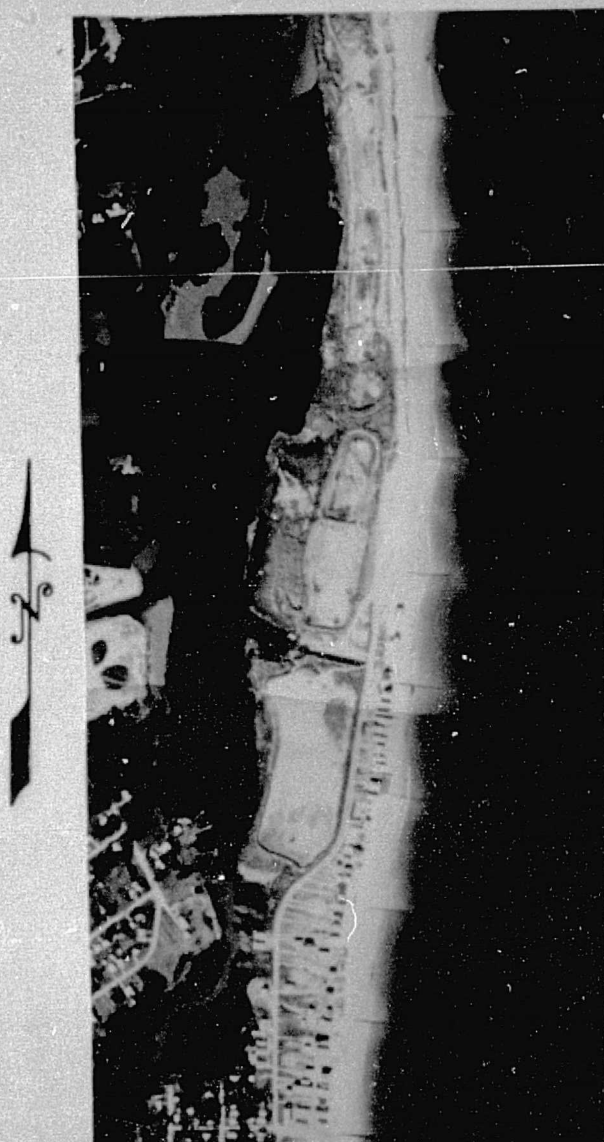
DECISION

The City of Hampton has responded to the VIMS recommendations (see letter in Appendix) by submitting a new permit application for future action to the Army Corps of Engineers.

The new application sets the limit to development at the marsh boundaries determined by VIMS remote sensing (with a protective setback distance). Proposed dredging is revised from

Figure 14. Color photomosaic of Salt Ponds, Hampton, Virginia.

Salt Pond Creek
Hampton, Virginia



Virginia Institute of Marine Science
Remote Sensing Section
Gloucester Point, Virginia

Format 70mm color
Altitude 3,000 ft Scale 1:11,000

Figure 15. Color infrared photomosaic of Salt Ponds, Hampton, Virginia.

Salt Pond Creek
Hampton, Virginia

Virginia Institute of Marine Science
Remote Sensing Section
Gloucester Point, Virginia

Format 70mm color infrared
Altitude 1,200 ft/366m Scale 1:4400
October 22, 1975

470,000 cubic yards below mean low water (MLW) to 88,000 cubic yards, and 130,000 cubic yards above MLW to 4,000 cubic yards, a total reduction of 86%. Channel depth is revised from 12 feet to 6 feet. New methods are proposed to stabilize dredge spoil in disposal areas, and to control sedimentation and erosion during dredging.

The VIMS remote sensing survey has thus resulted in major changes to the project plan, particularly the preservation of 60 acres of marsh. Remote sensing was the primary data source. It was essential for accurate up-to-date mapping. The permit application has been approved by VMRC, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and EPA. The approval of the Virginia State Water Control Board and the U.S. Army Corps is still pending.

8. CHAPEL CREEK WETLANDS PROTECTION

THE PROBLEM

The Mathews County Wetlands Board was approached in early 1975 by a private landowner seeking approval for alteration of an 80 hectare site on the Piankatank River consisting of a lake, wetlands, and stream outlet. This site, called Chapel Creek, was envisioned as a small boat harbor and marina. The Board sought advice from VIMS as to the value of the wetlands and the impact of development on the natural features of the site.

VIMS was asked for its assessment within four weeks, because Commonwealth County Wetlands Boards are required by law to hold public hearings on permit applications within 30 days of the filing of the application.

Site visits revealed a linear channel for Chapel Creek which raised the suspicion that modifications had been carried out at some time in the past. Consequently, a search for a photographic history was conducted, to allow determination of when suspected modifications may have been carried out.

It was also decided to obtain new aerial photography of the site, to enable VIMS personnel to determine wetlands areas with better accuracy, and to reveal present land use of the surrounding terrain.

METHODS

A search was conducted of the VIMS Photo Library for historical coverage of the site. New aerial photographic coverage was obtained in 70 mm format with a Hasselblad camera flown on the VIMS Beaver aircraft. The flight took place on January 15, 1976 at altitudes of 305 and 610 m. Coverage was obtained of the Chapel Creek area, and of adjacent shoreline in separate flight lines up and down river for several miles. This additional coverage will allow future changes in the area to be assessed against an existing data base.

Old and new photography was interpreted for the sequence of historical changes. New area measurements were made of the biota on the site. Surrounding land was interpreted for land use.

RESULTS

The earliest photograph available was from 1935. It showed the linear channel for Chapel Creek, and its terminal meander at the Piankatank River shoreline. Thus, if the creek channel was modified, it must have been modified prior to 1935. The configuration since 1935 is obviously stable.

The new photography was processed and enlarged to color prints which were assembled into a photomosaic (Figure 16). Scale on this mosaic was calculated from image features and a 1:24,000 topographic map. From the scale, area and line measurements were carried out, and resulting data presented to the Wetlands Board orally and by means of mosaic acetate overlays. Of particular importance were the area of the wetlands, and the length of the channel in existence at present.

Figure 16. Color photomosaic of Chapel Creek, Mathews County, Virginia.

Chapel Creek
Mathews County, Virginia

Virginia Institute of Marine Science
Remote Sensing Section
Gloucester Point, Virginia

Format 70mm color
Altitude 2,000' Scale 1:3,000
January 15, 1976

The proposed modifications were only roughly outlined in the permit application by the landowner. The scaled photomosaic allowed VIMS personnel to inform the Wetlands Board members specifically what was proposed by the developer. A proposed channel dredging of only roughly specified length, and a proposed dredge spoil disposal, were quantitatively evaluated with the assistance of the scaled photomosaic. Board members were enabled to see exactly what other alterations of existing wetlands were in prospect, and to visually appreciate the significance of the VIMS assessment.

DECISION

After presentations and review, the Mathews County Wetlands Board rejected the proposed development. VIMS used a photomosaic and photogrammetric measurements to show that a developer's proposed marina would result in direct destruction of one acre of marsh, and alter or threaten five additional acres. Stereoscopic evaluation of the imagery revealed the presence of steep banks on the surrounding water body which would be eroded by boat wakes. The Board denied the development permit by a vote of 3 to 1.

The remote sensing was crucial to understanding the developer's hazy proposal, to allowing quantitative evaluation of the threatened marsh, and to convincing the Board of the unique fragility of the marsh and its setting.

Two newspaper articles reporting the outcome are included in the Appendix.

9. YORK RIVER OIL SLICK TRAJECTORY PREDICTION

THE PROBLEM

The AMOCO Oil Refinery of Yorktown has been formulating plans for expansion of refining capacity from 50,000 barrels per day to 125,000 barrels per day. Recently, AMOCO made a presentation before the York County Planning Commission in relation to adoption of a restrictive zoning ordinance, pointing out that expansion was necessary to retain a competitive position with respect to other refineries located in this region, and that lack of permission to expand would lead "inexorably" toward closing of the refinery. It is expected that some expansion will be approved, and incorporated by amendment into the proposed zoning ordinance.

The extent of the expansion signals a markedly increased tanker traffic on the York River by 1980. Already, tankers of larger than previous size have off-loaded Venezuelan crude as a test of routing and loading procedures envisioned for the future. Dredging of the York River channel will be required to accommodate the draft of these larger tankers when fully loaded.

Oil spills of increasing frequency and volume will be a greater danger with the increase in tanker traffic and refinery output. At present, there is no effective Coast Guard Capability for handling oil spills on the York River, in that the only nearby Coast Guard facility is a Training Base. Moreover, the extent of knowledge of York River circulation is scanty. Previous studies of circulation have emphasized data relevant to one-dimensional mathematical models, in which river flank details have been neglected. The data are too sparse to allow development of surface circulation maps useful for predicting oil slick motion and assisting in oil spill cleanup.

REMOTE SENSING METHOD

The dye buoy/remote sensing method is efficient and convenient for mapping surface circulation patterns over a region. Methods such as a current meter study would be more expensive, and less directly applicable to oil slick motion, because current meters measure Eulerian data at points while oil slicks follow Lagrangian trajectories.

Expansion of our technique will be required for the large area of the lower York River. More buoys will be needed, more boats, and more extensive aerial photography. Tests have demonstrated that dye buoy plumes are recorded on color imagery at scales of 1:60,000. It is planned that some of the York River experiments will be conducted during a NASA Ames flight over the lower Bay. This coverage is scheduled to include at least three sequential passes over tidal regions of interest, including the York River with scales of 1:60,000 in 9-inch format.

Imaged buoy positions will be digitized, reduced to current vectors, and plotted to show a current vector field. To elucidate the influence of wind on the local current vector field, data will be collected in several dominant wind conditions. Maps will then be constructed which are appropriate for the selected wind conditions.

The current vector data will subsequently be used as input to an already-developed computer program. This program calculates oil slick motion for a given current regime and wind vector as a function of time (MacIntyre _et al._, 1970). Oil slick trajectories predicted by this program were compared in earlier studies with actual slick trajectories, and found to be in general agreement, but improvement was desirable (Munday _et al._, 1970). We concluded then that much improvement would result from use of more comprehensive tidal-current data than the sparse point data available in National Ocean Survey tidal current tables. The technique now developed for photogrammetric current surveys will provide the necessary density of data points at low cost.

Flood tide convergence zones mapped in earlier studies in Hampton Roads were found to recur in successive tidal cycles. The York River circulation near the Coleman Bridge has been observed in a cursory way for several years by various VIMS personnel. The observations consistently reveal foam lines and shear zones in particular locations during particular tidal phases. Mapping these features along with the current vector field is straightforward using the technique developed. It is nevertheless understood that the detail in these data is insufficient to reveal river flank secondary circulation, and convergence zones and foam lines, which are known to significantly affect oil slick motion. Thus, new data collection efforts will be required if substantial progress is to be made toward the goal of accurate trajectory prediction.

STATUS

Several days of observations over half tidal cycles have revealed a recurring progression of foam lines in particular locations in the lower York River. Old circulation data collected by the Smithsonian Institution have been examined and they lack sufficient detail to reveal water mass trajectories to use in oil slick tracking and cleanup. Hydrographic data, including current meter data collected by VIMS over the past decade, are being considered for their utility; particularly, study is underway into acceptable methods for generating Lagrangian surface current vectors from Eulerian current meter data. If such methods can be developed, the older data will be useful in generating predicted oil slick trajectories.

10. ELIZABETH RIVER OIL SLICK TRAJECTORY PREDICTION

THE PROBLEM

In previous remote sensing work at Newport News Point in Hampton Roads (Neilson, 1975), and in the York River near Gloucester Point, color boundaries were noticed to appear with regularity in certain phases of the tidal cycle. At Newport News Point, these features were analyzed with the dye-buoy remote sensing technique, which elucidated the directions of flow in the regions of color boundaries. It was discovered that the flow regime produces convergence patterns which have the effect of sweeping large areas of the water surface free of surface films and debris. This finding led to the recommendation that such convergence zones might be exploited for oil spill cleanup (see Fang et al., 1975; Munday et al., 1975).

The U.S. Coast Guard, 5th District, in Portsmouth, has the responsibility for oil spill cleanup in the Hampton Roads area and the lower Chesapeake Bay, as well as adjacent nearshore waters of the continental shelf of the Atlantic Ocean. This responsibility is vested in the Marine Safety Office. Personnel of this Office have found by experience that most oil spills requiring cleanup in the Hampton Roads area occur in the Elizabeth River. Despite the fact that the Elizabeth River is confined, in comparison to the rest of Hampton Roads and the Chesapeake Bay, there is still a problem during cleanup in predicting the direction and speed of oil slick motion. Coast Guard personnel need a better method than "eyeball prediction" for projection of oil slick motion. Moreover, better oil slick motion prediction would make possible a higher rate of success in identifying oil polluters. Since successful prosecution of oil polluters usually results in collection of fines, which are cycled into a fund used to finance oil spill cleanup, better oil spill motion prediction can indirectly aid in cleanup by making additional funds available.

A presentation was made in December, 1975, to the Marine Safety Office by VIMS personnel, describing the discovery concerning potential oil spill "carpet sweeper" convergence zones. The Coast Guard response was to strongly encourage new data collection and production of readily usable maps and other devices for real-time prediction of oil spill motion. Several specific sites in the Elizabeth River were pinpointed as being of immediate concern, where materials provided by VIMS could be of immediate benefit in oil spill cleanup. These sites include the Norfolk Exxon pier, the Craney Island Navy fuel depot, and the Naval base piers. Other sites of interest are the Chesapeake Bay mouth pilot station, the Thimble Shoal Channel at the intersection with the Chesapeake Bay Bridge and Tunnel, and the East and West Anchorage Areas for the Port of Norfolk in Hampton Roads.

THE CHOICE OF REMOTE SENSING

The Elizabeth River study performed in early 1975 produced a significant portion of the data that will be needed. New experiments will be needed to complete the necessary data base. The dye buoy remote sensing technique has already proved to be most direct and economical method for obtaining surface current data relevant to oil slick motion. Therefore, new experiments based on this technique are in progress as of summer, 1976.

METHODS

Some data produced by the Elizabeth River oil terminal study (Fang et al., 1975) were never reduced. These data are being reduced, and together with data reduced earlier, will be examined for coverage of the specific sites of interest. At present it is known that the Exxon pier requires additional coverage in some wind vector and tidal phase conditions. A computer program suitable for reducing digitized buoy data to vector maps is in development.

Dye buoy experiments are in progress as of summer, 1976, under varied wind vector and tidal phase conditions at sites lacking complete coverage.

Surface current vector field (circulation) maps will be produced by automatic computation for various combinations of wind vector and tidal phase. An index will be prepared in the form of a condition array, which is a plot of instances of existing data sets as a function of wind vector and tidal phase. This index will enable the Marine Safety Office personnel to rapidly select the regional circulation map which suits the existing conditions during oil spill cleanup.

STATUS

Reduction of older data, and collection of new experimental data, are in progress at the present time. Presentations of preliminary results are planned for late 1976. These preliminary results will be immediately usable by the Coast Guard; subsequent presentations will complete what will be called an Elizabeth River Circulation Atlas.

11. DYKE MARSH RESTORATION

THE PROBLEM

The National Capitol Park Service plans to make alterations in Dyke Marsh on the western shore of the Potomac River south of the Capitol Beltway near Washington, D.C. Inasmuch as the marsh was larger in the past, the project is a restoration; however, there is a question whether the decrease in size has been natural or induced by man. Information is needed about the marsh history, and particularly, the extent of man's impact, in order for a restoration to be carried out which truly restores the marsh to its former, natural configuration.

Dredging of sand from the Potomac River bed adjacent to Dyke Marsh is known to have taken place in the 1930's. It is not known at present whether this dredging directly or indirectly affected the size or morphology or plant distribution on Dyke Marsh.

Dyke Marsh restoration is seen as a beneficial use of dredge spoil currently being generated by dredging programs of the U.S. Army Corps of Engineers. The Corps Waterways Experiment Station in Vicksburg, Mississippi is engaged in a project to test the feasibility of marsh construction using dredge spoil. Windmill Point on the James River was studied earlier and some assistance was provided to the Corps by VIMS under the auspices of this NASA grant. The Dyke Marsh project is slightly different, in that restoration of a previously dredged area is being considered.

The questions involved in the proposed Dyke Marsh restoration are: 1) has the marsh changed in the past 50 years; 2) have changes been natural or induced by man's activities, particularly by dredging; 3) what is the present vegetation inventory of Dyke Marsh; 4) what should be the boundaries of the marsh after restoration; and 5) should revegetation be induced, or should the restored area be allowed to revegetate naturally. The answer to these questions will permit a restoration plan to be designed, and then restoration can proceed according to the plan.

USE OF REMOTE SENSING

The need is obvious for a search of aerial photographs taken of the area over the past 50 years. New photography is also needed to show the conditions prevailing at the present. In particular, the morphology and vegetative cover can be analyzed easily and inexpensively using aerial photography in answering the questions which have been posed. NASA Wallops Flight Center has been requested to obtain new color infrared photography of the area. The project is being coordinated by the Ecological Services Laboratory of the National Capitol Park Service.

METHODS

Aerial coverage was completed by NASA Wallops in February, 1976. A recommendation made by VIMS was adopted that the photographic flight lines include coverage from just north of the Capitol Beltway to a point several miles south of the marsh. This recommendation was based on the fact that changes relevant to Dyke Marsh may have been occurring in areas some distance from Dyke Marsh, and that dredging activity is likely in Hunting Creek just south of the beltway.

A vegetative inventory of Dyke Marsh was completed in 1975 by VIMS, but was based mainly on site visits and existing topographic maps. This inventory will be checked and made more accurate by interpretation of the new imagery.

The Photo Library at VIMS is being searched for past aerial photography. One photograph taken in 1935 has been uncovered. Vegetation boundaries and the marsh boundary will be traced on a 1:24,000 scale base map for each year of photography available, using a Bausch & Lomb Zoom Transfer Scope.

Recommendations for restoration based on the results will be prepared and communicated to the National Capitol Park Service.

STATUS

The VIMS vegetation inventory has been conveyed to the Park Service. The 1935 photograph, when compared to the details of the present inventory, reveals that there has been substantial decrease in the size of Dyke Marsh, but little change in plant communities in terms of either relative size or composition. Work is continuing.

12. HUGHLETT POINT REFUGE PLAN

THE PROBLEM

The U.S. Army Corps of Engineers, Norfolk District, has requested assistance in finding historical photographs and interpreting the wetlands history of the Hughlett Point region of Northumberland County on the western side of the Chesapeake Bay. This region contains a 100 acre marsh which the landowner would like to see preserved as a wildlife refuge. The landowner has been seeking guidance from several federal agencies on steps needed to protect and enhance the natural features of the area.

A photographic history is needed to show the region in the past, and the extent of natural and man-caused change. Land use, vegetational changes, and marsh boundaries can be determined by photo interpretation. Standard photogrammetric measurements may be needed as well.

STATUS

A search for available photography has been made in the VIMS Photo Library. Coverage extends from 1937 through 1970. Analysis of the imagery has begun.

PART FOUR: ASSISTANCE TO OTHER VIMS PROJECTS

ASSISTANCE TO OTHER VIMS PROJECTS

Assistance has been provided this year under the auspices of this grant to three other general programs.

COASTAL BARRIER AND DUNE DYNAMICS

Study of the Virginia Shoreline from Virginia Beach to North Carolina is being conducted by Dr. Victor Goldsmith. Photogrammetry of shorelines and dunes of Virginia and North Carolina is being exploited to elucidate coastal dynamics. This research study, funded by the U.S. Coastal Engineering Research Center and assisted by remote sensing, will have significant impact on coastal land-use practices of both Virginia and North Carolina. Both states are assessing land-use policy in the controversial area below Back Bay National Wildlife Refuge. Aerial photography is the only data source, other than field surveys to obtain ground control for new imagery. This study has major implications for the Back Bay National Wildlife Refuge. This grant has provided assistance to the shoreline study in the form of image interpretation, development of photogrammetric techniques, and selection of imagery in appropriate formats.

WETLANDS PERMIT EVALUATIONS

Continuing development pressure on Virginia wetlands is being met more and more often with analysis and interpretation of aerial photography. VIMS now reviews many wetlands permit applications forwarded from the Virginia Marine Resources Commission by means of aerial photography, which is faster than ground survey and permits quantitative measurements of marsh areas. VIMS personnel can make more informed recommendations to VMRC. This has a significant impact on wetlands protection because VIMS recommendations are generally accepted without alteration by VMRC.

In addition to the specific wetlands projects described elsewhere, numerous other wetlands projects of the VIMS Wetlands Section have been given low-level assistance. The assistance has consisted of acquisition and processing of aerial photography, image interpretation, training in use of the Bausch & Lomb Zoom Transfer Scope, and use of other image analysis devices.

FISHERMANS ISLAND VEGETATION MAPPING AND EROSIONAL HISTORY

Aerial photography of Fishermans Island was supported in the previous contract year. This year, minor assistance was provided to Mr. Mark Boulé in support of his analysis of the imagery (Boulé, 1976). Mr. Boulé has mapped the vegetation of the island in its present form, and prepared maps showing the island's morphological changes over the past 70 years. These maps will be of value in the present legal dispute over ownership of the island between a settler and the U.S. Department of the Interior.

Astonishing changes in the morphology of Fishermans Island at the mouth of Chesapeake Bay have been uncovered by this study.

The Director of the National Wildlife Refuge on the Island has declared these findings have forced him to adopt a new management policy of permitting natural changes to occur unimpeded.

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APPENDIX A

USER DOCUMENTATION

[illegible]

February 19, 1976

Dr. Bruce Neilson
Associate Marine Scientist
Va. Institute of Marine Science
Gloucester Point, Virginia 23062

Dear Bruce:

As requested at the last meeting held in the water control offices 1/28/76 regarding the Nansemond sewage treatment plant, I am forwarding to you the background data which we used as our stand and a subsequent letter which is a review of additional information as regards the proposed Nansemond sewage treatment facility.

In both of these instances we used the isocol date supplied by your office and identified in "Fine Scale Calculation Near Fox Trot in Hampton Roads Virginia" by Christopher Welch and Bruce Neilson.

I would like to comment that the information you supplied was quite advantageous and necessary in order for us to make a valid evaluation of environmental impact of the Nansemond sewage facility on the Hampton Roads area.

We appreciate your fine assistance and cooperation in this regard.

Sincerely yours,

Cloyde W. Wiley, Director
Bureau of Shellfish Sanitation

CWW:gmd

Enclosures

February 4, 1976

Mr. E. R. Simmons, Director
Division of Construction Grants
Virginia State Water Control Board
P. O. Box 11143
Richmond, Virginia 23230

Dear Mr. Simmons:

At the inter-agency meeting held on January 28, 1976 in the State Water Control Board offices, it was requested that the Bureau of Shellfish Sanitation reconsider the "buffer zone" that would be necessary for the proposed Nansemond Sewage Treatment Plant based on the following:

1. Secondary treatment plant designed for 12 mgd average flow.
2. Dechlorination of effluent.
3. Four hour retention basin.
4. Six hour retention time and outfall.
5. Interconnect capability with other HRSD facilities.
6. Use of microscreening or mixed filters.

1. The new proposal is for a secondary sewage treatment plant of 12 mgd design flow instead of the previously proposed 16 mgd plant. While this proposal represents a decrease in the design flow of 4 mgd, we are of the opinion that this decrease in flow does not warrant a reduction in the initial size of the shellfish buffer zone. Virginia Institute of Marine Science dye studies indicate that the area of influence at an 8 mgd flow is very nearly as extensive as that of the 16 mgd flow. In addition, the Bureau of Shellfish Sanitation is extremely concerned with the public health significance of heavy metals, toxic chemicals, viral and bacteriological pathogens, hydrocarbons and other possible "exotics" normally discharged into the sewage plant effluent. This concern necessitates the establishment of a conservative "buffer zone" of one mile in all directions if only secondary treatment is provided. Bioassays are to be conducted by the State Water Control Board around the plant outfall to determine the full impact on the marine environment. The results of these studies in conjunction with comprehensive bacteriological studies of the "buffer zone" and the surrounding area may allow a reduction in the size of the condemnation after the plant becomes operational.

2. Implementation of dechlorination at the Nansemond Sewage Treatment Plant will effect neither the degree of treatment or the disinfection. It will prevent discharge of chlorine compounds to the James River. Consequently, a reduction in the one mile "buffer zone" cannot be justified on this basis.

3. Construction of a four hour retention basin will serve only to increase plant reliability. Retention basins of this nature are generally used to hold unacceptable plant effluent or excess raw sewage flows. Use of this type of emergency holding facility is indicative of an unusual situation, ie., plant upset, hydraulic overloading, componet breakdown, etc. Since the "buffer zone" is based on routine plant operation the presence of a retention basin is insufficient cause for reduction of the "buffer zone".

4. The additional retention time (6+ hours) in the plant outfall provides no additional treatment or disinfection. It only provides additional time to effect an emergency closure of the lower James River should catastrophic conditions result in a complete breakdown of the treatment facility. The retention time in the outfall pipe was considered in the evaluation process for the one mile "buffer zone".

5. The Nansemond Treatment collection system will be interconnected with HRSD facilities in Norfolk and Virginia Beach. This will allow transport to and treatment of 3 to 10 mgd of raw sewage at the Chesapeake-Elizabeth Plant or the proposed Atlantic Plant.

Theoretically, the Nansemond Sewage Treatment Plant will initially be treating flows significantly less than its designed capacity. Use of the interconnect system is indicative of a major plant malfunction. This condition is not representative of normal plant operation. Should such a condition exist, it is probable that an emergency closure of the James River would have to be effected regardless. Consequently, interconnect capability would not effect the recommended size of the "buffer zone" around the plant outfall for normal operating conditions.

6. The use of mixed media filters or microscreening following secondary treatment has been proposed. In discussing with the Bureau of Sanitary Engineering, it was verified that the use of such filters would not be approved unless preceded by chemical addition, flocculation and sedimentation. The proposal therefore, becomes essentially identical to the previously recommended AWT. Should AWT be provided, the "buffer zone" would be reduced to ½ mile and be completely contained within the present condemned area.

On February 2, 1976, Mr. William J. Love, HRSD, asked that we incorporate in our consideration an additional 1600-1700 foot extension of the outfall beyond the VIMS recommendation "North of the 36° 56' latitude". The previous proposal (based on one mile) required the additional condemnation of some 540 acres of shellfish growing area. The 1600 foot additional outfall extension would reduce the condemned area to 281 acres. Accordingly, a portion of the mile radius "buffer zone" would extend outside the present condemnation.

As previously stated, items 2, 3, 4 and 5 primarily give increased reliability to item one or the facility with a design flow of 12 mgd. Historically, sewage treatment plants require enlargement soon after being built. As indicated above, item 6 in effect is a proposal for AWT which would require a buffer zone of ½ mile in all directions.

Therefore, based on the foregoing considerations, the Bureau of Shellfish Sanitation maintains the position that initially, a one mile "buffer zone" in all directions from the end of the proposed Nansemond Sewage Treatment Plant outfall will be necessary, irrespective of decisions made on items 1 - 5 above. The implementation of item 6 would of course, greatly reduce the size of the "buffer zone" and is highly recommended by this agency. Also, extension of the outfall line in the direction recommended by VIMS will reduce the size of any additional shellfish area condemnation proportionally.

Should it be decided to extend the outfall an additional 1600 feet, approximately 281 additional acres of shellfish growing area will be condemned, based on secondary treatment and the proposed mile buffer. Consequently, the Bureau of Shellfish Sanitation recommends that a public hearing be held to determine the socio-economic effect of the proposed Nansemond Sewage Treatment Plant on the shellfish industry.

Thank you for the opportunity to comment on these proposals. Should you have any questions, please let me know.

Sincerely yours,

CWW

Cloyde W. Wiley, Director
Bureau of Shellfish Sanitation

CWW:smh

cc: Mr. O. L. Brown
Dr. R. L. Wood
Mr. O. A. Adams
Mr. G. T. Yagel

Bureau of Shellfish Sanitation
Virginia State Health Department

Recommendations Concerning Proposed
Nansemond Sewage Treatment Plant

I. HRSD Design and Location Proposed

(a) If the present need and location for a STP in the Hampton Roads area is accepted, the following should be taken into consideration relative to Shellfish Sanitation Controls.

(b) The Bureau of Shellfish Sanitation recommends that effluent line and/or diffuser from the proposed STP be located north of 36° 56' latitude.

In addition to being inside of already condemned shellfish area No. 7, this location places the bulk of the flow in a pattern or flume that flows upstream and within the channel of the James River. It is believed the Recommended Location will prevent a considerable portion of the effluent flow from going up the Nansemond River. Being in a channel, greater depths also provide greater dilution capabilities.

II. Recommendations for Advanced Waste Tréatment (AWT)

Degree of Treatment:

After secondary treatment as listed below in III, a ballast and retention pond, Chemical addition, Flocculation, Sedimentation, Filtration and Chlorination should be provided.

Considerations:

When employing AWT the effluent will contain approximately 5 - 10 mg/l BOD and Suspended Solids. This degree of treatment will guarantee practically complete disinfection, ie., the fecal coliform MPN in the effluent will approach 0/100 ml. Breakpoint chlorination followed by

COMMONWEALTH OF VIRGINIA

VIRGINIA INSTITUTE OF MARINE SCIENCE
GLOUCESTER POINT, VIRGINIA 23062

January 15, 1976

Mr. James Ashley
Public Works Department
City of Hampton
30 N. King Street
Hampton, Virginia 23669

Subject: Comments and recommendations for an inlet modification into the Salt Ponds in the City of Hampton

Dear Mr. Ashley:

We have utilized the information you have supplied us on tidal flow and the information available in our files to make a first order estimate of the inlet design question. The limits of available information and time constraints preclude a complete inlet analysis and design. We have, for example, not made any study of the structural elements such as materials required and specifications. These matters should be done by professional design engineers. Our remarks are intended to evaluate the feasibility of the project and to indicate likely environmental effects.

It will be useful, as background, to comment initially on the characteristics of the coastal reach between Old Point Comfort at the entrance to the Hampton Roads and Northend Point, at the mouth of Back River. This reach is about eight miles in length. The inlet to the Salt Ponds is about 4½ miles north of Old Point Comfort. The segment of coast to the south of the inlet is either completely stabilized by bulkhead or partially stabilized by groin fields. The apparent direction of net sand drift is to the south.

The segment of the coast north of the inlet, about 3½ miles in length, may be divided into two compartments at Lighthouse Point. The spit north of Lighthouse Point experiences a net sand drift to the north. Between Lighthouse Point and the inlet the net drift is likely to be to the south. For the most part the shoreline north of the inlet is unstabilized.

It is important to note that, due to the relatively short reach of unstabilized coast the magnitude to littoral drift is not large.

Let us now turn to the inlet question. The design of stable tidal inlets is still a difficult subject in coastal engineering. Most inlet design is done with an imperfect understanding of the processes involved. However, it is recognized that stability pivots around the relationship of the volume of water going in and out the embayment by tidal flows and the magnitude of sand drift across the entrance tending to close the entrance. If there is sufficient flow to keep the inlet open the cross-sectional area of the inlet channel will adjust to maintain a balance between the scouring force of the tidal currents and the sand carried into the inlet. Thus, there is a natural condition which will fluctuate in time in response to changing wave and tidal conditions. Most inlet modifications are to widen or deepen the channel and to stabilize the entrance with jetties which represents a departure from natural dynamic equilibrium. Such is the case at hand. Given this, the problem becomes one of trying to predict the effects of the modification.

The Salt Ponds receive tidal flows from the inlet and from Long Creek. The simultaneous measurement of tidal flow at the inlet and at Long Creek indicate there is only a small volume input via Long Creek relative to the inlet. Thus, for a first approximation the Long Creek input and outflow may be ignored.

The following information applies:

a) Spring tide range outside Salt Ponds = 3.0 ft.
b) Mean tide range outside Salt Ponds = 2.5 ft.

c) Surface water area of Salt Ponds = 2.43×10^6 sq.ft.
d) Surface area of marshes = 0.95×10^6 sq.ft.

e) Cross-sectional area of inlet channel (MSL) $\simeq$ 250 sq.ft.
f) Maximum inlet channel depth (MSL) $\simeq$ 4 ft.
g) Estimated inlet channel width $\simeq$ 100 ft.

h) Based upon a one tide cycle observation it appears that the tide range within the Salt Ponds is the same as the local range in Chesapeake Bay.

i) Tidal prism in Salt Pond based upon <u>water</u> surface and mean range = 6.08×10^6 cu.ft.

An empirical relationship exists which relates the equilibrium cross-sectional area of the inlet channel to the tidal volume gated by the inlet. Using the tidal current information obtained by your office on 9/22/75 the tidal colume was computed to be 8.96×10^6 cu.ft. Comparison of the calculated "expected" channel cross-section and that observed is as follows:

"Expected" cross-section for unstabilized inlet $\simeq$ 170 sq.ft.

"Expected" cross-section for inlet stabilized by 1 or 2 jetties $\simeq$ 380 sq.ft.

Observer cross-section (9/22/75) $\simeq$ 250 sq.ft.

The existing inlet to Salt Ponds is partially stabilized by one groin on the north side of the entrance. This fact, plus the fact that the wave energy at the inlet is smaller than those cases used in deriving the empirical relationship lead to the conclusion that the existing inlet channel is in apparent "equilibrium" with existing tidal volumes and sand drift.

The question now turns to what may be expected to occur within the system given the proposed project of deepening the inlet channel and installation of jetties. The City of Hampton has indicated the harbor is intended for use by traffic running the Inter-Coastal Waterway and therefore desires a channel depth of 6 ft (MLW). In addition navigation and steerway considerations would probably require an 80 to 100 ft. width between jetties. Allowing for about a 4 to 1 side slope and a 60 ft. wide constant depth section results in project cross-section at mean low water of 500 sq.ft. At mean tide level the cross-section area would be about 620 sq.ft. Thus, relative to mean tide level, the project cross-section would be about 2.5 times the existing cross-section. This condition should not be expected to be a stable cross-section since the flow speeds will be reduced and some shoaling of the channel can be expected. Peak currents prior to shoaling will probably not exceed 1.5 ft/sec. It is not possible to predict the magnitude or rate of shoaling. However, maintenance dredging <u>must be anticipated</u>. For cost estimation purposes you might consider ¼ of initial volume annually.

The principal purpose of the jetties is to stabilize the inlet against passage of littoral drift sand directly into the inlet.

Without jetties the shoaling would be rapid and the now existing complex nearshore topography would remain. With jetties one would still expect some complex topography at the end of the jetties but direct movement of sand into the inlet at the beach face is prevented. Although this is beneficial from the point of view of inlet maintenance a trade-off must be accepted. The jetties act as a barrier to littoral sand drift: in the present case the supply of sand from the north will be interrupted. Thus, maintenance (and initial) dredging should be planned so as to place the sand size spoil on the beaches to the south of the inlet.

The question of the length of the jetties is a complex of environmental, engineering and cost considerations. For example, construction costs would make it impractical to extend the jetties all the way out to existing 6 ft. water depths. It would likely be less costly to accept the cost of maintenance dredging for the leg from the end of the jetties to the 6 ft. contour. I believe a pair of 400 ft. jetties perpendicular to the shoreline will serve for stabilization.

Given the above explanations we offer the following comments and recommendations.

1) A stabilized inlet at the Salt Ponds is feasible but to gain a useful width and depth of channel the needed cross-section area will result in reduced flow speeds leading to shoaling and the channel will require maintenance dredging.

   In order to be useful for the intended purpose of access by boats requiring 6 ft. water depth we suggest a channel cross-section of 100 ft. width with a 60 foot width center section at 6 ft. depth (MLW) and tapered side slopes.

2) We suggest a pair of 400 ft. long jetties perpendicular to the coast with the width between jetties at 100 ft. We recommend that the jetties be stone in place of sheet pile.

3) Initial dredging will require continuation of the access channel to existing 6 ft. depth MLW.

4) The tidal flushing of the Salt Ponds itself would not be adversely affected by the proposed action.

5) Sand dredged during the initial project and in subsequent maintenance actions should be used to

nourish the beaches on the south of the inlet since the inferred net littoral drift along the coast will be restricted and trapped on the north side of the north jetty. Part of the dredged sand should be used to fill the compartment which will exist between the new southern jetty and the northernmost groin in the groin field south of the inlet.

If we can be of further service to you on this matter we will do our best to help.

Sincerely yours,

Robert J. Byrne, Head
Dept. Geological Oceanography

RJB:cbo

City of Hampton

OLDEST CONTINUOUS ENGLISH-SPEAKING SETTLEMENT IN AMERICA
HAMPTON, VIRGINIA 23669

March 5, 1976

Dr. John Munday
Virginia Institute of Marine Science
Gloucester Point, VA 23062

Dear Dr. Munday:

I wish to express my appreciation for the outstanding assistance given to the Public Works Department of the City of Hampton in preparing photographic and associated documentation for our Salt Ponds project.

The information provided was of more substantial value that similar information obtained using conventional methods. The high resolution and outstanding quality of the work would be difficult to obtain elsewhere.

Thank you again for your most agreeable and professional assistance.

Sincerely,

R. Wayne Johnson

R. Wayne Johnson, P.E.
City Engineer

RWJvjr

Gazette-Journal, Gloucester, Virginia February, 1976.

Chapel Creek Dredge Request Dumped By Wetlands Board

By Phil Hayward

An application for dredging and marine construction on Chapel Creek along the shoreline of Hesse in Mathews County met 3-1 opposition last Wednesday from the Mathews Wetlands Board at a special hearing accompanying its monthly regular meeting.

The board's decision followed reports from scientists from the Virginia Institute of Marine Science (VIMS) and comments from the general public. Twenty persons from the public attended the meeting.

Hesse is a 300-acre estate purchased last year by McDonald Lee Stephens of New Orleans. Although Stephens has made no specific decision, he has indicated though his agent, the Richard E. Callis Co., that he intends to sell all but 31 acres of the estate.

The application, filed by Richard E. Callis, called for dredging 800 feet offshore in the Piankatank River and extending the 50-foot wide channel directly inward for another 1,200 feet into Chapel Creek at a depth of four feet below mean low water.

In addition to the dredging, the application sought permission to install jetties 1,000 feet into the Piankatank and to slope off the remaining 1,000 feet of marshland with vegetation.

The Wetlands Board consulted VIMS, which compiled a report based on their onsight inspection of the proposed project and aerial photography. In presenting their report, VIMS scientists James L. Mercer and Gary L. Anderson said their chief area of concern stemmed from the indirect developments of the proposed wetlands activity. Mercer said the possibility of erosion and sedimentation was their chief concern.

Since development of part of the 300-acre tract may be planned by the owners through partial residential development and timber sales, Mercer said there are gaps in their information. He said a lack of knowledge of the number of possible lots, their location and density were the items missing in their report.

"We feel that at this time without further information, our assessment is incomplete," Mercer said.

The board based its decision on VIMS' conclusion that approximately 44,000 square feet — a little more than an acre — of pristine marshland would be destroyed.

Wetlands board member Russell Bradley said he opposed the application because "wetlands laws specifically state that the public benefit and deprivation should out-weigh the private good."

Board chairman James E. Odom in listing his reasons, said from the standpoint of the Wetlands Board, he could see only one possible gain in the project — "that there would be better discharge from Chapel Creek." Although at its deepest point, Chapel Creek is seven feet deep, it has zero depth at its mouth, board members said.

Mercer earlier told the meeting that the increased flushing capacity of Chapel Creek would make more organic matter available to marine life in the Piankatank.

Odom listed the destruction of marshland, a high degree of erosion of more marsh and the damage accompanying the development of the surrounding land on the northshore as his reasons for voting against the application.

Board member Ervy M. Hudgins said if the channel is opened to a depth of four feet at a width of 50 feet, the resulting boating activity would contribute to considerably more erosion.

As the only board member to vote in favor of the application, George De Marco based his decision on existing erosion.

"With the proper precautions, there was already some environmental degradation taking place," De Marco said. "With the proper engineering, the effects of further work would not affect that degradation."

(continued on page six)

Chapel Creek

(continued from page one)

"There's no doubt that land values will increase," he said. "It's naive to think this land will remain pristine — that's the trend."

Prior to its vote, the board fielded questions and comments from the general public. Objections to the application centered on the lack of control once the project is completed. People were also concerned with the effects of attendant boat traffic.

In stating their report to the Wetlands Board, the VIMS officials outlined two alternatives to the original proposal for dredging that would help to leave Chapel Creek in its original form. They suggested an open-pile marina in the mouth of Chapel Creek. A less-favored alternative of creating a boat basin on the existing pond just inside the mouth of the creek was also suggested.

The board informed Callis at the meeting that he has the choice of resubmitting the application with specified changes or appealing the decision to the Virginia Marine Resources Commission.

Callis said last Friday that he had received no decision from the Stephens family. He said, however, he expects a decision from Stephens by Friday. A resubmittal of the application would most likely be the forthcoming decision, Callis said.

In other business, the Wetlands Board approved a one-year extension for Raymond B. Smith of Mathews for the construction of an open-pile pier and boat house on Stutts Creek. Odom said the request was approved because of Smith's wait for approval from the Army Corps of Engineers.

Mrs. Roland Wilson of Mathews was named by the board to replace outgoing secretary Mrs. Russell Bradley upon her resignation effective at the February meeting.

Daily Press, Newport News, Va. February, 1976

Chapel Creek Work Rejected By Board

By TOM ROWE
Staff Reporter

MATHEWS — The Mathews County Wetlands Board has turned down by a 3-1 vote a proposal for extensive work in Chapel Creek on the Piankatank River as a part of development of "Hesse" property which recently changed ownership.

The action came at a public hearing attended by about 40 persons Wednesday night and was substantially based on a report from the Virginia Institute of Marine Science (VIMS) which cited dangers to the marine environment.

Submitted by Richard E. Callis of Cobbs Creek, a contractor and agent for McDonald Stephens, owner of "Hesse", the proposal included dredging a channel and small boat basin and constructing a pier and boathouse.

James E. Odom, chairman of the Wetlands Board, said the proposal was rejected because of specific and potential damage it would cause.

George De Marco, the only board member to vote for it, contended the environment was already severely degraded and the work would not significantly increase that condition.

Odom, along with Russell Bradley and Ervy M. Hudgins, held that to the contrary, of all places in Mathews County, this was probably the least degraded. "VIMS considers it pristine," Odom said. "It has a highly valued marsh . . . number one in vegetation and organic production."

Landowners in the area were lukewarm regarding the project, Odom said, neither violently opposing it nor supporting it.

The VIMS report, prepared by J.L. Mercer and G.L. Anderson, said proposed channel modifications in Chapel Creek would directly destroy approximately 44,604 square feet of highly valued wetlands.

The potential for shoreline erosion would be created by increased boating traffic creating wave energy in the form of wakes. Future lot owners would inherit the problem, the scientists said.

The report said a direct result of dredging the channel would be the loss of organisms that live along the creek bottom. Sedimentation and increased turbity would be by-products of the dredging. It also noted "a number of other adverse effects."

The Wetlands Board invited Callis to resubmit the application with one of two alternatives suggested by VIMS — construction of an open-pile marina extending into the Piankatank River or a community boat basin and ramp in the existing pond/marsh area. The first alternative, more desirable than the second, VIMS said, would eliminate most of the adverse impacts of the original proposal as well as provide a facility for residents who don't live on the creek.

The applicant has the right to appeal the board's decision to the Virginia Marine Resources Commission. Callis indicated at the hearing he will consult with Stephens before a decision is made.

In other matters the board granted Raymond B. Smith his second one-year extension on a permit to dredge a boat basin and install a mooring slip and bulkheading on Stutts Creek. Smith said he has been delayed in his work awaiting a permit from the U.S. Army Corps of Engineers.

The board accepted the resignation of Mrs. Russell Bardley as secretary and named Mrs. Roland Wilson of Mathews to replace her.

APPENDIX B

PRESENTATION ON SEWAGE OUTFALL SITING USING REMOTE SENSING

Virginia Institute of Marine Science

Gloucester Point, Virginia 23062

SEWAGE TREATMENT PLANT OUTFALL SITING USING REMOTE SENSING

1975 - 1976

(The following information may help in presenting the accompanying slides.)

SLIDE 1. OYSTER BEDS THREATENED BY PROPOSED SEWAGE OUTFALL SITE.

The Hampton Roads Sanitation District Commission has decided to build a new sewage treatment plant to serve the needs of Portsmouth and Nansemond County, south of Hampton Roads, Virginia. Because Hampton Roads has great dispersion capability, the proposed plant will be located at Pig Point, with its outfall pipe leading out into Hampton Roads. In an earlier study (1975), VIMS determined the diffusion and dispersion capability of the general area first proposed for the outfall, using a dye release from the abandoned munitions pier (the incomplete pentagonal shape) located in the center of Hampton Roads. The results of this earlier study indicated that the seed oyster beds to the west would not be severely affected by effluent from the pier area. These seed oyster beds are critical to the Virginia oyster industry as they are the largest and best oyster beds in the James River, which produces virtually all seed oysters for the Chesapeake Bay oyster industry. Then, a precise outfall site southeast of the dye release point was proposed, to allow the outfall pipe to be placed adjacent to the route of a proposed new bridge-tunnel. Concern was expressed by the Virginia Bureau of Shellfish Sanitation that flood tide flow past this

SLIDE 1 (cont'd.)

new site might split, with a portion directed into the Nansemond channel and toward the oyster beds. VIMS was asked to perform a new circulation study to address this single concern as quickly as possible.

SLIDE 2. OUTLINE OF THE PLANNING AND DESIGN PROCESS.

In the planning of a sewage treatment facility with large potential impact on the environment, on a major seafood industry, and on regional development patterns, the decision-making process is complicated, with the involvement of all the parties who are likely to be affected. This process is outlined on the slide, and the strategic part of the path affected in this case by the remote sensing study is emphasized at the bottom. The central player is the Hampton Roads Sanitation District Commission (HRSDC), which is the agency having responsibility and resources to construct and operate sewage treatment facilities in the Hampton Roads region. HRSDC normally works through consulting engineering firms in planning and designing new facilities. The consulting firms generally obtain site-specific environmental data from local resources, in this case, VIMS. With the aid of environmental data, the consulting firm prepares recommendations for HRSDC, which then presents the plan as a permit application to appropriate state and federal agencies with specific interests and permit powers. These agencies generally hold one or more public hearings in the course of reviewing the permit applications. It was during one of these reviews that the question was raised as to the danger of the new site to the oyster beds. HRSDC raised the question in turn to the consulting firm, which passed it on to VIMS. VIMS answered the question and made a recommendation entirely on the basis of remote sensing, and approval for the VIMS recommendation was subsequently obtained from all interested parties. Thus there was a direct line between the remote sensing and its application, embedded strategically at the end of the decision pathway.

SLIDE 3. THE DECISION TO USE THE REMOTE SENSING TECHNIQUE.

The remote sensing technique developed under the NASA grant was particularly suited to the solution of the problem at hand. It is characterized by a flexibility for tidal situations, which allows highly specific experiments to be designed and performed efficiently and quickly. It is this characteristic which matched the potential of remote sensing to the requirements of the situation. All of the alternate approaches were more cumbersome and costly, less precise, or too far removed from the actual situation to be credible. For example, dye studies cost five times as much, and produce good diffusion data but poor flow data. Current meter studies are more cumbersome and costly, and less precise both in terms of spatial resolution and elucidation of Lagrangian flow. Physical model studies suffer the lack of precision of current meter studies because physical models are based on current meter studies. The suitability of the remote sensing technique and the low relative cost were strong incentives in persuading the Hampton Roads Sanitation District Commission to bear a portion of the costs of this study. This user acceptance and support ensure that the technique will be used by VIMS beyond the demonstration phase and the seed support of the NASA grant.

SLIDE 4. FEATURES OF THE REMOTE SENSING TECHNIQUE.

The experimental technique combines classical photogrammetric elements of remote sensing with floating dye-emitting buoys and a vessel. This combination provides maximum operational control for an on-site work period of at least six hours (a half-tidal cycle). The dye buoys emit dye at the water surface, and are both free-floating and anchored. Each is labeled with a unique identifier. The remote sensing vehicle is a small aircraft, flying at between five and ten thousand feet, with a Hasselblad 70 mm camera and Ektachrome high speed color transparency film. The aircraft is used as a spotter to direct the vessel by radio to particular dye buoys for identification. Dye images on time-sequential photographs are digitized and reduced to current vectors. The technique is easily adaptable to drogued buoys measuring currents at any depth, so that tidal circulation can be efficiently and precisely mapped using remote sensing.

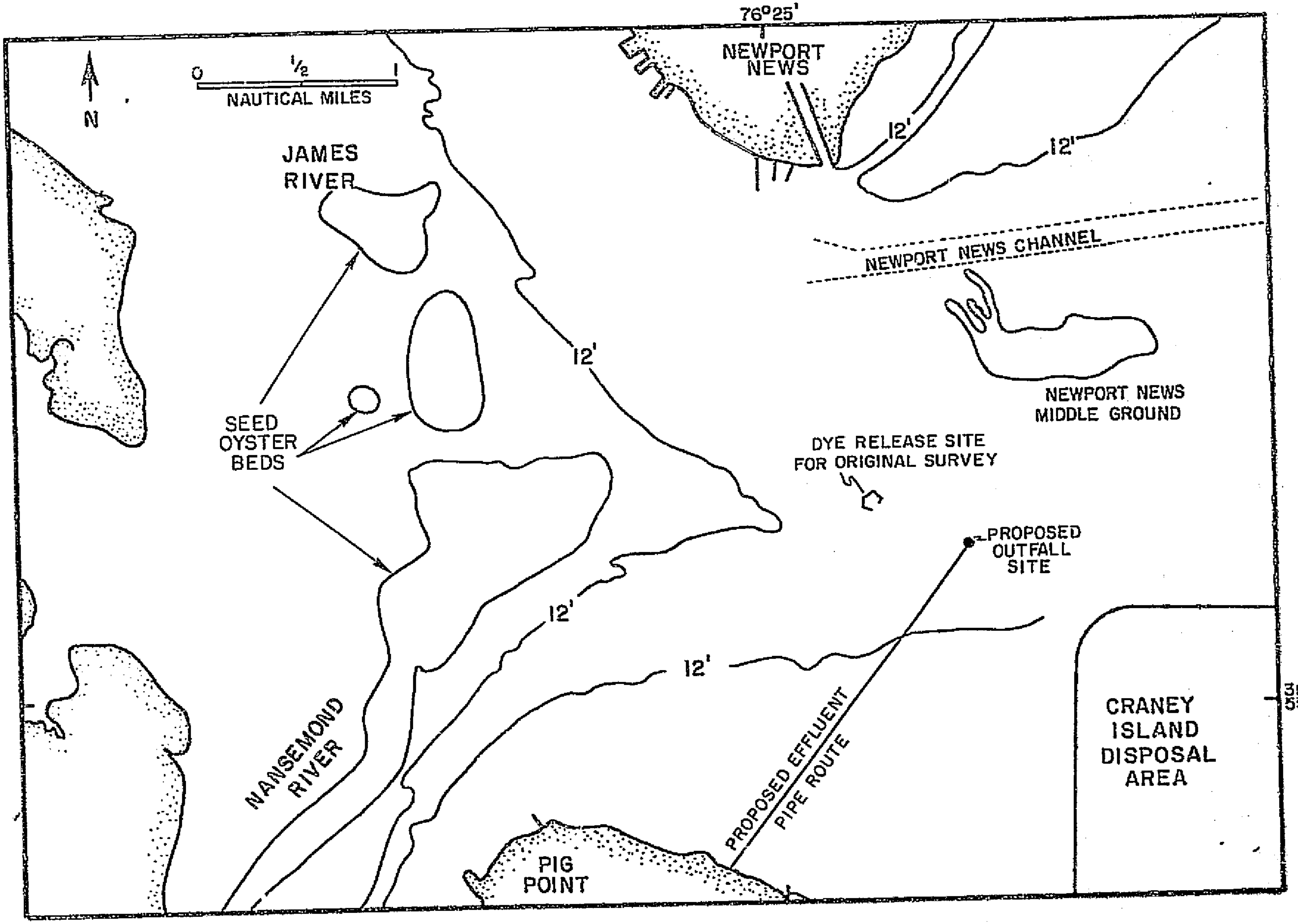
In this study the decision on initial placement of dye buoys was made with substantial help from NASA high altitude imagery. In 1972, color infrared and thermal infrared scanner imagery were obtained in a sequence of NASA passes during a half-tidal cycle. Interpretation of this sequence revealed that west of the proposed outfall site, the James River started to ebb sooner than the Nansemond River, allowing the possibility that James River water might cross Nansemond Ridge toward the Nansemond River mouth. This finding caused VIMS to place extra dye buoys in a north-south pattern westward of the site, in order to discover exactly when and where the flow lines which pass the site would diverge, and which portion would more directly reach Nansemond Ridge.

SLIDE 5. EXPERIMENTAL RESULTS AND RECOMMENDATION.

The results of the experiments showed that effluent from the site would reach the oyster beds, and that a relatively short extension northward of the outfall site would keep effluent away from the oyster beds. In particular, during the early part of the flood, waters flow past the entire study area toward the Nansemond County shoreline, but never reach the significant oyster beds. During middle and late flood tide, the flow splits just to the south of the site of the original study, the southern path leading toward the Nansemond River and the oyster beds. The VIMS recommendation to move the site northward was for the purpose of keeping the effluent in the northern branch of the flood flow, during middle and late flood. In order to be easily and clearly understood, the VIMS recommendation was phrased in terms of a square area within which the outfall could be safely placed. The recommendation was based entirely on the remote sensing data.

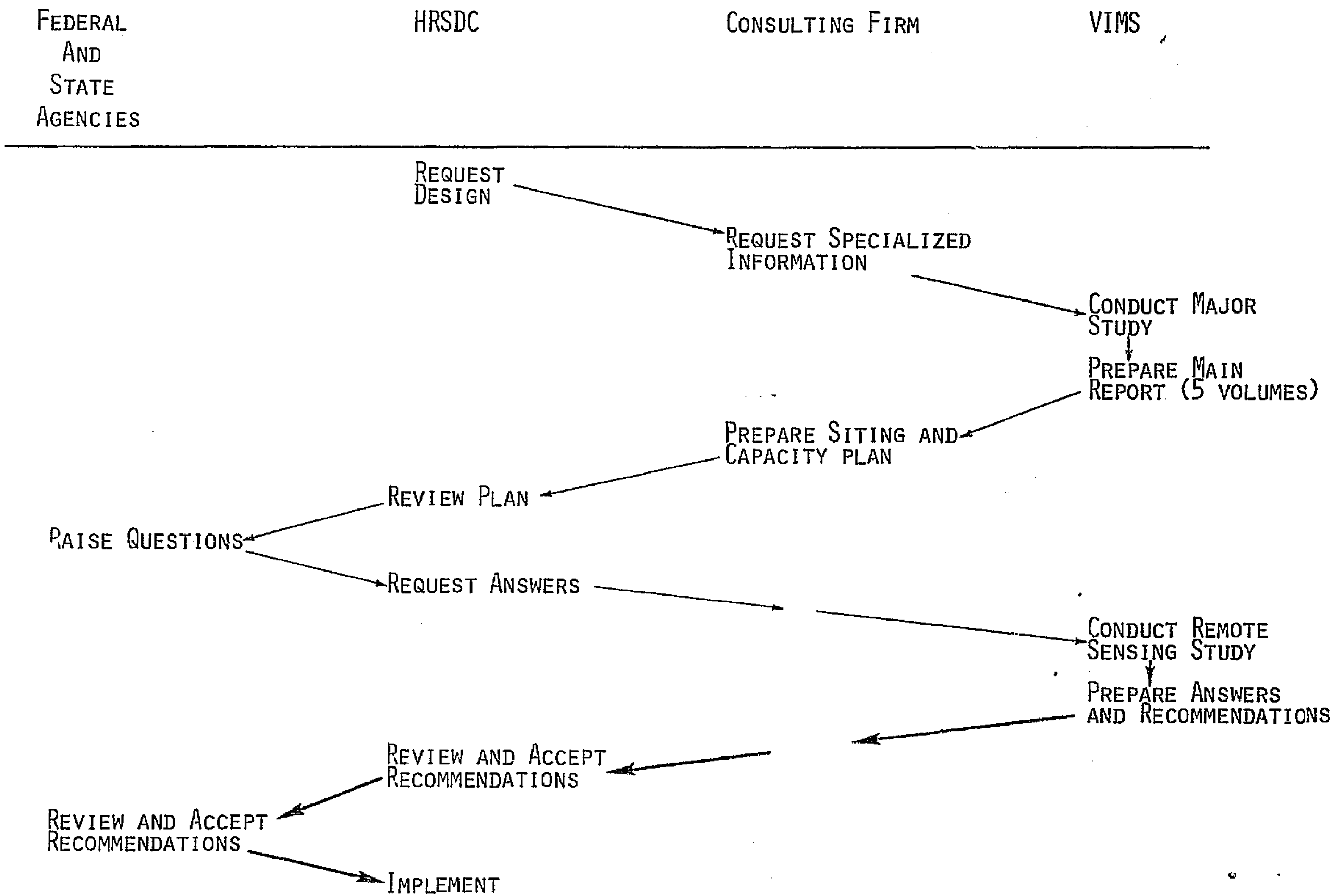
SLIDE 6. CONSEQUENCES AND OUTCOME.

The VIMS recommendation for a more northerly site for the outfall, based on remote sensing, was adopted by HRSDC. This new site was then accepted by the Virginia Bureau of Shellfish Sanitation, the agency which had raised the question. The new site is being included in the design plan, and is expected to be used for the actual construction, when it occurs. The result is that the critical seed oyster beds of Nansemond Ridge, because of the remote sensing study, will be better protected than they would have been under the original plan.



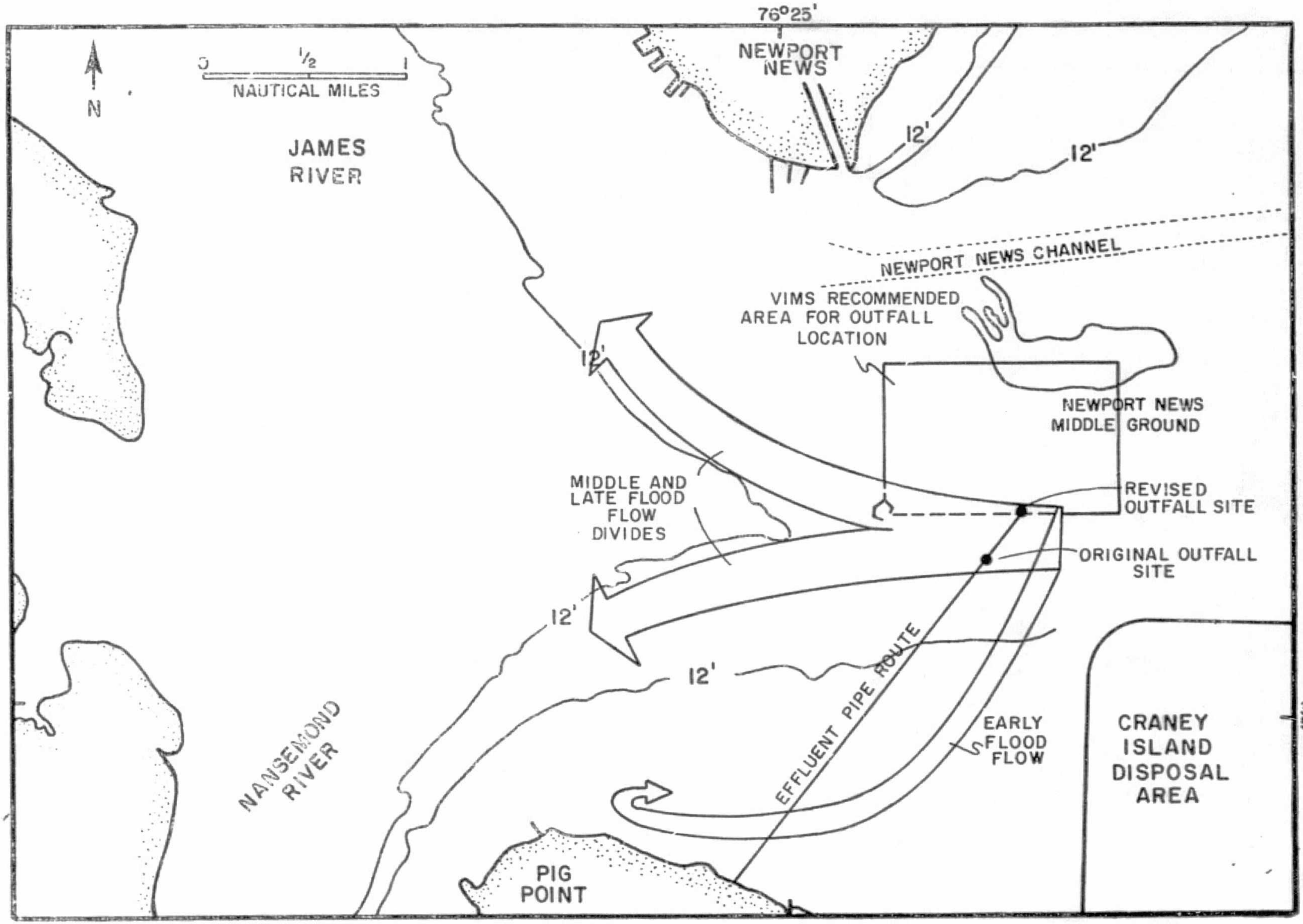
Q = IF THE SITE OF THE SEWAGE TREATMENT PLANT OUTFALL WERE LOCATED AS ORIGINALLY PROPOSED, WOULD SMALL SCALE CIRCULATION CARRY EFFLUENT TO OYSTER AREAS?

DECISION FLOWCHART



FACTORS LEADING TO USE OF REMOTE SENSING

1. MOST DIRECT ROUTE TO A SATISFACTORY ANSWER : HIGH PRECISION LAGRANGIAN INFORMATION IN ACTUAL WATER BODY.
2. SHORT TIME TO COMPLETION.
3. LOW COST
   - A. FIVE TIMES CHEAPER THAN OTHER METHODS
   - B. REMOTE SENSING COSTS BORNE PRIMARILY BY USER.
4. LOW VULNERABILITY TO VESSEL TRAFFIC AND OTHER EXPERIMENTAL HAZARDS.



INTERPRETATION & RECOMMENDATION

CONSEQUENCES OF THE REMOTE SENSING STUDY

A. HRSD DECIDED TO CHANGE PROPOSED OUTFALL SITE TO NEW AREA RECOMMENDED BY VIMS ON THE BASIS OF REMOTE SENSING DATA.

B. REMAINING RESPONSIBLE AGENCIES GAVE APPROVAL FOR NEW SITE.

C. NEW SITE TO BE INCORPORATED IN DESIGN PLANS.

D. OUTFALL WILL BE BUILT AT NEW SITE.

E. NANSEMOND OYSTER BEDS WILL BE PROTECTED FROM SEWAGE EFFLUENT.