Task 8 - "Feasibility of MIPS for SAV Studies"

Feasibility of MIPS for SAV Studies

Final Report

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FEASIBILITY OF MIPS FOR THE COLLECTION AND DISPLAY OF INFORMATION ON THE DISTRIBUTION AND ABUNDANCE OF SUBMERGED AQUATIC VEGETATION

VIRGINIA INSTITUTE OF MARINE SCIENCE
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Feasibility of the Map and Image Processing System (MIPS) as a Device for the Collection and Display of Information on the Distribution and Abundance of Submerged Aquatic Vegetation from Aerial Photographs

by

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Cover Photo: Digitized aerial photograph of the Potomac River south of Washington, D.C., 2 Sept. 1987, altitude 12,000 feet, by AEROECO Inc., Edgewater, MD, scanned into MIPS at Salisbury State Univ, MD. SAV bed outlines in yellow.

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Executive Summary

An evaluations of the Map and Image Processing System (MIPS), as a device for the collection and display of information on the distribution and abundance of submerged aquatic vegetation (SAV) from aerial photographs, has been conducted using MIPS workstations at Salisbury State University, Salisbury, MD and the Virginia Council on the Environment (Va. COE), Richmond, VA. The results indicate that MIPS has the capabilities to process SAV aerial photographs and extract coverage data that are accurate in both size and position. Extracted coverage data may be imported into a variety of geographic information systems (GIS), including ARC-INFO and the Map Overlay and Statistical System (MOSS), for further processing and analysis. Results relating to specific objectives of the evaluation are given below.

1. **Costs** - System costs range from $16,000 for an introductory system to $40,000 plus for a complete system capable of scanning, processing, storing, and exporting natural resource digital image and geographic data. Data acquisition and processing times are comparable to those for manual processing systems, such as the College of William and Mary / Virginia Institute of Marine Science (W&M / VIMS) SAV GIS. Additional time spent for data entry in MIPS (scanning aerial photographs for digital image acquisition) or geographic rectification of scanned photographs is offset by time savings in interactive natural resource feature identification, editing, and export routines. The level of personnel required to operate MIPS is comparable to that required for manual analysis of natural resource coverage data.

2. **Accuracy** - Data accuracy is comparable and consistant with the source geographic data sets examined in the study, namely 9" by 9", 1:24,000 vertical panchromatic (black and white) and color aerial photographs and 7.5 minute, 1:24,000 United States Geological Survey (USGS) topographic quadrangle maps. MIPS map rectification routines were used to fit SAV coverage data derived from scanned aerial photographs to scanned images of associated 7.5 minute quad maps. Positional and areal differences between MIPS processed data, and similarly processed VIMS SAV GIS data were examined. Average positional differences were on the order of 30 meters or less for known geographic landmarks as well as for SAV bed outlines appearing on both maps and aerial photographs. Average areal differences between MIPS, VIMS SAV GIS, and pc ARC-INFO were on the order of 17,250 square meters (2 - 5 percent of the corresponding areas) for known geographic test areas, and 25,000 square meters (30 - 31 percent of the corresponding VIMS SAV GIS areas) for actual SAV bed areas.

3. **Data Portability** - Natural resource features, whether point or polygon, in gridded (raster) or coordinate (vector) format, are easily exported to external data files for subsequent entry into various GIS's. MIPS can export data in formats compatible with popular GIS's (e.g. MOSS, ERDAS, ARC-INFO, GRASS, etc.).

4. **Requirements for Aerial Photographic Source Data** - The most critical and fundamental step in the entire process of determination of SAV

distribution and abundance is the source data acquisition phase. For SAV aerial distribution, low level (altitude), vertical, aerial photography is the current standard by which SAV bed images are obtained. The acquisition phase is governed by strict guidelines restricting windows of opportunity to certain season, tidal stage, atmospheric, and water quality conditions, and time of day. Unfavorable conditions associated with any one of these can easily mask SAV bed features, rendering MIPS and any other automated processing system unusable due to lack of sufficient feature information in the source imagery. Decreasing the altitude currently flown for SAV data acquisition (12,000 feet, 3660 meters) would increase windows available for acceptable photography. However, potential cost savings by MIPS would be offset by increased costs in the acquisition phase (lower altitude would require more flights and increased number of photographs per flightline). In addition, reducing the altitude would generate additional problems in certain regions of the Chesapeake Bay (e.g. Susquehanna Flats, Tangier and Smith Island) where SAV beds are either very large or so far from the shoreline, that adequate ground control points necessary for proper scale rectification of maps and photographs would be lacking. Possible solutions would be acquisition of SAV at variable altitudes or low level video. Because SAV is one of the most difficult resources to photograph and map, problems identified here in the acquisition phase would not necessarily apply for tidal or non-tidal wetlands.

MIPS worked well when using 9" by 9", 1:24,000, panchromatic or color, vertical, aerial, positive, photographic prints as the input data source. The evaluated MIPS workstations were configured with Howtek Color Scanmasters for acquiring digital image data from various sources, e.g. scanned photographs, maps, drawings, etc. The Howtek Scanmaster has user selectable scanning resolutions, with a maximum resolution of 300 dots per inch (dpi). The 300 dpi maximum closely approximates the resolving power of the unaided human eye. For 1:24,000 scale photography, 300 dpi scans produced images with resolution cells, or rasters, of 2 m by 2 m. At this resolution there was no noticeable loss of spatial information apparent in scanned photographic or map images. The MIPS workstations employed a graphics device capable of displaying 1280 horizontal (H) by 1024 vertical (V) rasters with up to 256 unique hues per raster. The gray tones of scanned panchromatic images closely matched those of the originals, with no detectable loss of tonal information.

For color images, MIPS has options for storing each primary color as an independent image (band) or optimally assigning color values to the resultant scanned color image. The user also has the option to interactively control color assignments. This was useful in scanning areas with SAV, as subtle differences in hues of dark brown, green, and blue-green contain critical information relating to SAV distribution and abundance. Even with the interactive control of color assignments, there were instances where subtle changes and gradations in hue, apparent in the original image, were not captured and displayed in the scanned image using the color optimizing option. Because the original photographs were available for immediate reference, this did not present serious problems when interactively tracing SAV coverages with a manually controlled screen pointing / drawing device ("mouse") on the 1280 H by 1024 V high resolution color monitor. This could present problems when using semi or fully automated feature identification routines which use color as a basis for feature classification. It should be noted that MIPS workstations can be configured with graphics boards with greater color display capabilities - 256 intensity levels for each primary color. This mode of color image processing requires each color image be stored and processed as three separate primary color images covering the same identical area. The degree of difficulty in identifying and classifying significant image features and the accuracy requirements of the particular application would be deciding factors in determining whether the advantages of higher color fidelity outweigh the corresponding increased storage and processing requirements.

The Howtek film scanner was not designed to scan 9" by 9" color film transparencies, and test aerial film transparencies had to be physically trimmed to 8.5" in width. The scanned images produced from the trimmed film transparencies had problems with color sensitivity and separation, with the displayed color images having noticeable color plateaus and contours, not evident in the original images. It should be noted that the evaluated photographic film transparencies had low inherent contrast, thus exacerbating the problem. Physical size limitations on input photographs and color problems encountered with film transparencies limits use of this data source with the current Howtek scanning system.

Air Video - MIPS was able to easily digitize aerial images of SAV acquired by video camera. For this study color, vertical, aerial video recordings of SAV beds located in nearshore regions of the lower York River, VA, from altitudes of 2200 feet and 4400 feet, were evaluated. The images were recorded in flight on a standard 0.5 inch VHS video cassette tape. Video data were entered into MIPS using a standard video cassette recorder (VCR) whose video signal cables were connected to the MIPS workstation. The recording was replayed on a medium resolution color monitor, suitable for display of the standard television images produced by the video system. Image selection is accomplished by viewing recorded moving images on the monitor and "freezing" or capturing the desired image by means of the mouse buttons. The inherent low spatial resolution of digitized video images (512 H by 485 V) is offset by low cost per image and continuous coverage capabilities that make acquisition of low altitude, large scale images affordable. Acquisition of complete, detailed, low cost coverage of SAV beds may be improved by the use of aerial video images, as long as adequate ground control points are available in the video imagery for proper map rectification and processing costs per image remain reasonable.

5. **Clarity and Ease of Interpretation of Final Mapping Product** - In the case of SAV distribution and abundance analysis, the final mapping products are outlines (polygons) of SAV beds, uniquely identified by geographic coordinates (latitude / longitude, UTM, etc.), user

defined labels, and associated information relating to species composition, distribution, abundance, and other items. For other natural resource applications, the final mapping product might be quite different, such as scanned and rectified aerial photographs or satellite images. Focussing on SAV applications, the outlined SAV beds were very easy to identify, delineate, and edit. The mouse driven cursor was smooth and precise. MIPS is very "user friendly" and has emulated elements of popular personal computer (pc) graphics / paint software routines to make the outlining process easy and natural.

There are a variety of methods for rectifying MIPS derived SAV outlines to a map base, thereby transforming the outlines from relative screen coordinates to absolute geographic coordinates. This process involves the use of maps that are either scanned into the system or available as archived scanned images. MIPS map rectification routines were used to accomplish the coordinate transformation. Transformations were accurate within the displayed resolution of 1 minute of latitude (approximately 34 meters). Images containing SAV outlines were rectified and transformed to a base map coordinate system by identifying a number of evenly distributed geographic point features (typically 6 - 10 features - bridges, road intersections, prominent shorelines, streams, etc.), visible in both the scanned image and scanned / rectified map of each particular area. This map registration / rectification approach has the advantage of correcting for problems associated with scale differences between aerial photographs and base maps, and oblique aerial photograph geometries resulting from off-vertical camera angles during photograph exposure. Comparisons between MIPS identified SAV features and corresponding VIMS SAV GIS identified features resulted in average positional differences of 34 meters. Polygon statistics, including area, perimeter, roughness, centroid, and type, were produced in user selected measurement units and displayed on the monitor and / or written to disk file as character data for subsequent analysis. The geographic, lat. / lon., SAV vector files produced by MIPS were easily written to floppy diskette in either MOSS or ARC-INFO format, and subsequently entered into the W&M / VIMS Prime minicomputer and pc ARC-INFO system for visual display and analysis.

6. **Usefulness of Final Mapping Product** - Timely, accurate, digital SAV coverage data produced by MIPS will be very useful to the continued operation and development of SAV distribution and abundance studies, and similar natural resource studies. Third party systems, such as MIPS, ARC-INFO, and others, have inherent advantages of economies of scale over user designed systems, provided the user's needs are compatible with third party products. If this is the case, processing improvements and expanded capabilities provided by MIPS will provide scientists and managers with increasingly economical and powerful tools to assist in the analysis and management of critical natural resources.

Conclusions - The feasibility study has demonstrated that MIPS is capable of being used as a device for the accurate collection and display of information on the distribution and abundance of SAV from aerial photographs. MIPS supports on-screen delineation of SAV, thereby eliminating the need for tracing SAV outlines on translucent base maps. Map rectification procedures used in MIPS operate independently of photograph and map scale, making MIPS amenable to analysis of current or historical photographic data at a variety of scales. For SAV, this scale independent feature provides a great deal of flexibility in planning and execution of aerial photographic surveys by broadening the range of available flight altitudes, so that adjustments can be made to compensate for adverse haze effects experienced during summer periods of peak SAV growth. Comparisons of areal statistics indicate relatively small (5 percent) systematic differences between similar geographic test areas processed by MIPS, VIMS SAV GIS, and pc ARC-INFO. Comparisons of areal statistics for SAV beds served to determine combined systematic and individual photo-interpretive differences. The combined differences were on the order of 30 - 31 percent. Systematic differences, therefore, accounted for 13 - 17 percent of the areal differences, with individual photo-interpretive differences accounting for the remaining 83 - 87 percent of the observed areal differences among the three systems. This indicates that most of the areal differences can be attributed to individual photo-interpretive skill and judgement, and supports the conclusion that a skilled SAV photo-interpreter would be able to produce accurate and consistent SAV areal statistics using MIPS.

MIPS has also demonstrated its utility in delineation of spatial features that have distinct color characteristics, such as tidal and non-tidal wetlands. In particular, wetlands have unique color characteristics which are amenable to MIPS manual or automated feature delineation routines.

Construction of photographic and map mosaics using MIPS may present problems when used in large, comprehensive studies with regard to the amount of data processing and storage associated with this operation. MIPS may present certain "bottlenecks" in the processing of large data sets, as processing operations are centered on each particular workstation, and not distributed for multi-user use. Multiple MIPS workstations would alleviate this situation by supporting simultaneous data processing.

Recommendations - Based on the favorable results of the feasibility study, it is recommended that the MIPS evaluation be continued on site at W&M / VIMS, in order to assess its incorporation and performance in operational SAV distribution and abundance studies. Through constant use, procedural development, and periodic assessment, during an annual inventory, the strengths and weaknesses of MIPS, in an operational setting, will become apparent.

The objective of continued operational evaluation of MIPS would be to develop a set of standard operating procedures (SOP's) for the use of MIPS in identification and extraction of natural resource coverage data (SAV, wetlands, shoreline features, etc.) from source imagery (photographic, video, or satellite). SOP's would cover source data requirements, system input methods, feature delineation routines, map transformation methods, quality control and assurance, incorporation of existing data sets (e.g. USGS DLG's), quantitative and qualitative feature attributes, data management, output data requirements, and interface with other GIS's.

A potentially valuable component of continued operational evaluation of MIPS would be detailed study of the incorporation of low altitude, video imagery in SAV and other natural resource inventories. If this medium is practical for use, it offers potential for increasing the range of acceptable atmospheric conditions for conduction of aerial surveys, thereby widening flight "windows", facilitating real-time data acquisition for critical environmental situations, and reducing collection costs. Another potential benefit from continued MIPS evaluation would be a thorough investigation of MIPS map registration and rectification routines as they relate to highly detailed natural resource feature mapping, such as tidal and non-tidal shorelines. Current rectification technology is not automated, and while very accurate, is slow and labor intensive.

Results of an operational evaluation of MIPS would provide scientists and managers with decisive information regarding advantages / disadvantages of the incorporation of MIPS in extensive natural resource inventory, assessment, and management projects.

A potentially valuable component of continued operational evaluation of MIPS would be detailed study of the incorporation of low altitude, video imagery in SAV and other natural resource inventories. If this medium can be used in a manageable, practical way, it offers the potential of increasing the range of acceptable atmospheric conditions for conduction of aerial surveys, thereby widening flight "windows", facilitating data acquisition, and reducing collection costs. Video also has the advantage of being an economical, real-time, remote sensing, image medium that is amenable to near real-time data collection, analysis, and response to critical environmental situations.

Another valuable component of continued MIPS evaluation would be a complete investigation of MIPS map registration and rectification routines as they relate to highly detailed natural resource feature mapping, such as tidal and non-tidal shorelines. Current instrumentation used for this purpose is manual, and while very accurate, the process is slow and labor intensive.

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Section 1

Introduction

This is a report of the results of an evaluation of the feasibility of the Map and Image Processing System (MIPS) as a device for collection and display of information on the distribution and abundance of submerged aquatic vegetation (SAV) from aerial photographs. The evaluation was directed to specifically address the tasks of collection, storage, and processing of high resolution environmental resource coverage data. As this was a feasibility study and no MIPS workstations were available on site at William and Mary / Virginia Institute of Marine Science (W&M / VIMS), initial evaluations of the capabilities and performance of MIPS were conducted during visits to the Image Processing Lab of Salisbury State University, Salisbury, MD, under the direction of Dr. K. Peter Lade. Final evaluations of MIPS were conducted during visits to the Virginia EcoMAP program (formerly the Virginia Rivers Inventory (VRI) program), Virginia Council on the Environment (Va. COE), Richmond, VA, under the direction of Dr. Adam A. Frisch.

Dr. Lade has been developing estuarine research and management applications using MIPS. He has assisted in the implementation of a MIPS based map / aerial photograph real-time indexing system for the Maryland Department of Natural Resources (Md. DNR) and has conducted SAV distribution and abundance studies of Maryland waters with MIPS, using SPOT satellite data as input. Visits to Salisbury State were made on 6 February, 14 - 15 March, 18 - 19 May, and 6 - 7 July 1989.

The evaluation was also based on results viewed during a working demonstration of MIPS given by Dr. Lee Miller - MicroImages, Inc. in Richmond, VA on 25 May 1989. Dr. Miller is the founder and distributor of MIPS, and his presentation covered many processing routines necessary for implementation of SAV distribution and abundance studies using MIPS.

Dr. Frisch is manager of the Virginia EcoMAP program. In support of that and other state programs, he is managing the installations of a minicomputer version of ARC-INFO and a network of MIPS microcomputer workstations. Due to the close proximity of Va. COE, final elements of this evaluation were conducted using the Va. COE MIPS during visits on 21 - 23 and 25 August, 8 and 18 September, 6 and 13 November, 6, 15, and 21 December 1989, and 3 and 4 January 1990.

In addition to "hands-on" evaluations and presentations of MIPS, the authors drew on their professional knowledge and experience in the fields of marine biology and botany as they relate to SAV distribution and abundance, and image processing and GIS as they relate to natural resource feature identification and mapping. Scientific tools are ever evolving, and this is particularly true with electronic / computer based analytical systems. With this in mind, the authors strove to temper the many "high-tech" elements of MIPS with the knowledge and experience gained during years of natural resource research and application studies. The result is an evaluation that benefits from careful review and consideration during the evaluation of optimal methods to determine SAV distribution and abundance, using available resource imagery and processing systems.

Project Description - This project evaluated MIPS software and hardware for use in environmental resource monitoring. The evaluation specifically addressed the collection, storage, and processing of high resolution environmental resource coverage data. Evaluations were also made as to the suitability of the data collected by MIPS for use by the ARC-INFO GIS.

The environmental resource used in the evaluation was SAV (Orth and Moore, 1983, Orth et al, 1987, Orth et al, 1989). The sources of SAV information were 9" by 9", 1:24,000 scale aerial photographs taken in 1987. The photographs provided a good basis for comparison, as they were previously used for annual mapping of SAV by the W&M / VIMS SAV program.

Evaluations were performed on sites in the Chesapeake Bay region that covered a broad range of environmental conditions and SAV plant species compositions. Evaluations were made by comparing MIPS methods of data collection to methods currently employed by the W&M / VIMS SAV program.

Rationale - There is an expanding need for high resolution digital environmental monitoring data. Before a resource such as SAV can be properly managed, monitoring programs need to be established and inventory data collected. Under existing methods these data are extremely expensive and difficult to obtain. Aerial photographs must be taken at specific altitudes and scales in order to achieve suitable correspondence with base maps. The necessary cameras, equipment, and aircraft required for this are very expensive. The resource information on these photographs must then be hand transferred into one of many geographical information systems before processing and analysis can be completed. All these steps require large amounts of time from a large group of highly trained and closely supervised technicians. The end result of the mapping effort is a digital data set comprised of polygons defining SAV coverages as well as a data record of SAV bed attributes. The polygons are used to produce a series of computer generated line map overlays.

To enhance monitoring of SAV and other environmental resources, such as wetlands, shorelines, and natural resource features included in the Virginia EcoMAP program, new methods are needed for streamlining the data acquisition phase, while maintaining or improving the same level of spatial resolution, quality control, and quality assurance. One tool showing promise as an environmental resource data collection device is the Map and Image Processing System. MIPS would allow the use of a much wider range of aerial photographic types and scales, without the use of physical magnification. This is especially important in examining historical trends when using old photography taken at non-standard scales. In addition, the use of lower altitude photography would significantly broaden the range of atmospheric conditions suitable for SAV data collection, such as reducing atmospheric haze effects which can obscure SAV boundaries. MIPS would allow the digitizing of resource boundaries directly on a video screen without the manual transfer of resource coverage from photograph to base map. This video screen digitizing process removes the need for separate data transfer and digitizing steps, thereby reducing the time and cost of data collection and at the same time reducing transposition errors resulting from multiple transfers of information from one media to another.

New methods and technologies need to be developed which will enhance the usefulness of the final mapping product to the environmental science community. Rather than simple line plot overlays, MIPS can produce orthophotograph maps from the original aerial photographs. These orthophotograph maps allow for much easier map reference point recognition as opposed to overlays on USGS topographic quadrangle maps.

Of the many possible resources that could be used to test MIPS, submerged aquatic vegetation is the most suitable for three reasons:

1. SAV has been and will be the focus of intensive bay-wide studies because of its overall ecological importance as well as its high degree of yearly variability.

2. SAV is one of the most difficult habitats to photograph and map, and as such, whatever procedures developed for SAV data collection and analysis could also apply to the monitoring of other marine resources such as wetlands and shorelines.

3. Digital SAV coverage data as well as the original aerial photographs used by the W&M / VIMS SAV monitoring program were available for the MIPS evaluation. Using the same aerial photographs is extremely important in order to conduct an unbiased comparison of data collection systems.

MIPS has been used extensively by the Maryland Department of Natural Resources for analysis and archival of large numbers of aerial photographs and for mapping wetland vegetation for zoning and Environmental Protection Agency (EPA) compliance. In addition the state of Delaware has contracted with Salisbury State University to use MIPS in tidal wetlands studies. University of Maryland's Chesapeake Biological Laboratory (CBL) is using MIPS as a general purpose image processor as well as a tool for spatial modelling. The Virginia Council on the Environment is using MIPS to assist in implementation of the Virginia EcoMAP program as well as to provide a means for incorporation of environmental data within state and local GIS's.

As expected in a state-of-the-art system, long term experience, even by current MIPS users, is limited. Therefore, it is important that state agencies review and evaluate the system before investing additional resources in its implementation. MIPS has the potential for greatly improving the use of GIS for resource monitoring, inventory, and analysis. Allowing the rapid input of a wide range of images, data, and maps into these geographic systems will greatly facilitate geographic studies conducted by organizations like Virginia EcoMAP, where a variety of different data sources are required. In addition, MIPS will allow for the convenient input of satellite and other remote sensing information that otherwise might not be easily managed and therefore available to these studies.

Objectives - Specific objectives addressed in the evaluation were determination of:

1. Data acquisition costs in terms of:
   - o Personnel hours of work required.
   - o Level of personnel expertise required.

2. Digital data quality and assurance with regard to:
   - o Systematic methods for error assessment.
   - o Recognition of spurious or missing data points.
   - o Spatial error of replicate measures of coverage boundary and area.

3. Data suitability and portability to other environmental analysis and geographical information systems.

4. Source aerial photographic requirements with respect to:
   - o Photographic clarity and scale.
   - o Ability to use historical photography.

5. Clarity and ease of interpretation of final mapping product.

6. Usefulness of the final mapping product to:
   - o Environmental scientists.
   - o Environmental managers on a federal, state, and local level.
   - o Interested lay individuals.

Section 2

Evaluation

Description of MIPS - The Map and Image Processing System (MIPS) is a microcomputer based, map-oriented, image processing system marketed by MicroImages, Inc., of Lincoln, Nebraska. MicroImages was founded in 1986 by Dr. Lee D. Miller, a university professor with more than 20 years of experience in the fields of cartography and remote sensing, gained while serving on the faculty of the University of Nebraska at Lincoln, Texas A&M University, and Colorado State University. In addition, Dr. Miller was a Senior Visiting Scientist at NASA Goddard Space Flight Center during a 2 year sabbatical. MicroImages currently employs a staff of 18 and has sold approximately 100 systems to federal, state, and local agencies, educational institutions, and private individuals.

MicroImages has focussed on designing a system that is compatible with the needs, requirements, and methods of natural resource scientists and managers. Efforts have concentrated on building a system that automates the process of remote sensing data input, feature identification, and output of natural resource features. MIPS processes both grid (raster) and coordinate (vector) based data, and can transform and integrate the two. Standard geographic digital data formats such as Earth Resources Data Analysis System (ERDAS), U.S. Army Corps of Engineers GRASS, U.S. Geological Survey (USGS) Digital Line Graphs (DLG), U.S. Fish and Wildlife Service (USF&WS) Map and Statistical Overlay System (MOSS), and Environmental Systems Research Institute's (ESRI) ARC-INFO are supported. Research and development efforts are focussed on software development and systems design, using available geographic, graphics, and imaging components.

MIPS hardware configurations are shown in Figures 1. and 2. MIPS operates on International Business Machines (IBM) Personal Computer (pc)-AT computers and other compatible microcomputers under the Microsoft Disk Operating System (MS-DOS). A schematic diagram of a complete MIPS workstation, with associated input, processing, and output units is given in Figure 3. As the software is brand and model independent, MIPS has capabilities for upward expansion as hardware and software systems improve. This was demonstrated recently, when MIPS upgraded to the recently introduced 32 bit pc-AT computers, based on the Intel 80386 processing unit ("386" pc's). MIPS utilizes dual screens, a high resolution 1280 horizontal (H) by 1024 vertical (V) color monitor for image display and a pc graphics monitor for program control. MIPS also employs a manually controlled "mouse" device which is electronically linked to the high-res color monitor for interactive identification and processing of features appearing on the screen.

Maps, graphics, and aerial photographs can be scanned into MIPS, in black and white or color, using a high resolution, 300 dot per inch (dpi), Howtek Scanmaster. Images and other geographical data sets are stored internally during processing on high capacity magnetic hard disk drives with storage capacities in the range of 150 million bytes (Mbytes). The disk drives are capable of storing approximately 100 optimized screen-sized color images per drive. Digital data from aerial, satellite, or other sensors, as well as data such as USGS DLG's, can be transferred to and from the system via 9 track magnetic tape, optical laser disk (write once, read many (WORM) or erasable), magnetic floppy disk, or telephone modem. Image, graphical, statistical, and operational output is accomplished via a 240 dpi, Howtek color printer or standard pc printer.

Processing under MIPS is conducted using a suite of hierarchal, pop-up, menus. The menus are used to direct users from general high level areas to more specific low level areas containing sets of tasks relating to the overlying high level functions. A brief outline of MIPS processing functions is given in Appendix A. A "Guide to MIPS" (Miller et. al, 1989) and "Basic Systems Operations" (Ghormley, 1989) are available from MicroImages as further system descriptions. MIPS processing functions can be regarded as a set of powerful tools that may be used in a variety of ways to achieve desired results. Depending on the application, certain functions will be called into play at various processing steps. MIPS also has available a set of file management, graphics, and image processing functions that may be called from virtually any point in the menu hierarchy using pc functional keys. Raster and vector data are grouped in a hierarchal file structure, that assists in file management by minimizing the number of independent files on the pc, while providing for full identification of file contents, and logical storage and placement of associated file components.

A fundamental aspect of MIPS processing is the **interactive** aspect of map, image, and geographic data processing. The system is designed so that the user is able to control, via the mouse and keyboard, each processing step. Results are viewed on the color monitor in real-time as they occur, thus facilitating immediate correction and improvement of each particular operation. This continuous feedback during operations reduces cumulative and systematic errors by enabling the user to assess the accuracy and correctness of each processing step by visual comparisons of the processed data with the original input image.

Plan of Work - The plan of work to accomplish the evaluation of MIPS, with regards to SAV research, included the following steps.

1. Familiarization with the Map and Image Processing System and its capabilities.

2. Development of MIPS methodologies for:

    - Scanning aerial photographs into MIPS
    - Rectification and map registration of aerial photographs.
    - Recognition and definition of SAV boundaries on the video screen.
    - Export of digital SAV boundaries from MIPS using standardized file formats.

3. Development of ARC-INFO methodologies for acquisition of MIPS SAV export files.

4. Collection and analysis of SAV coverage data using MIPS on two study sites.

5. Importation of MIPS coverage into ARC-INFO.

6. Digital comparisons of SAV locations and areas as determined by MIPS, ARC-INFO (using imported MIPS data sets), and by the independent VIMS SAV GIS.

7. Production of a final report delineating all points of comparison defined in the objectives including map overlays for the study sites of SAV coverages produced by MIPS, ARC-INFO, and the VIMS SAV GIS.

Detailed descriptions of each step follow.

MIPS Familiarization - Familiarization with MIPS was accomplished during test and evaluation sessions on MIPS workstations at Salisbury State University and Virginia Council on the Environment, demonstrations given by MicroImages, and reviews of MIPS documentation and articles. Tests and evaluations of MIPS performance using MIPS workstations took place throughout the study period and comprised a total of 20 daily sessions. As the study was directed at obtaining map coordinate based, SAV coverage data, the working sessions focussed on those functions necessary to accomplish this task. During the last few sessions, when the methodologies for SAV coverage extraction had been determined and the necessary coverages obtained, other complimentary features of MIPS were evaluated.

Dr. Miller and Mr. Mike Unverferth of MicroImages gave a working demonstration of MIPS to state and local agency personnel on 25 May 1989 in Richmond, Va. at a presentation sponsored by the Virginia Council on the Environment. The demonstration covered many of the areas addressed by this evaluation. It served to demonstrate how operations are accomplished, the processing times involved, and the quality of the results. Due to time constraints, data preparation and input were not included as part of the demonstration. In the absence of available instructional or reference material, the demonstration proved useful in determining whether or not certain operations were possible using MIPS.

It should be noted that MIPS is a rapidly evolving system. Only recently has MicroImages been able to provide detailed, hard copy, instructional material. Soft copy descriptions of various MIPS processing routines were provided on the pc monitor by means of "help screens" relating to processing steps or options. These were up to date and helpful as a memory aide during actual processing. Written documentation and instructions consist of:

1. A series entitled "MIPS Memo", published periodically to inform users of new features and capabilities and to address commonly asked questions.
2. A "Guide to MIPS" containing general descriptions of the various MIPS processing capabilities and procedures involved with conducting typical map and image processing operations.
3. A "Basic System Operations" instructional manual describing the rationale and specific use of all the MIPS functions.
4. Descriptions of available software and hardware configurations.

The "MIPS Memo" series and "Guide to MIPS" are helpful in describing the system, its development, and capabilities. For the new or occasional user, the "Basic System Operations" manual explains the operation of MIPS functions and provides detailed instructions on their use. As this study commenced before publication of detailed instructional manuals, the MIPS processing strategy was based on Dr. Lade's considerable experience with MIPS, suggestions from the staff at MicroImages, and trial and error.

MIPS Methodologies for SAV Data Processing - Methods were devised for using MIPS for the identification of SAV on scanned aerial photographs, registration and rectification of the SAV coverage data to a map based coordinate system, and export of the SAV coverage data in a standard file format. The methods were based on the input data medium, characteristics of SAV features, and desired output data format. Dr. Lade was of great assistance in piecing the individual processing steps necessary to achieve the desired results. The steps were as follows:

1. **Quad Map Scanning** - SAV coverage data derived from scanned aerial photographs require registration to known geographic locations in order to transform the coverage data into absolute geographic coordinates. To accomplish this, 7.5 minute USGS topographic quad maps of the two evaluation sites were scanned into MIPS at resolutions ranging from 150 - 200 dpi using MIPS "Prepare > Raster > Scan > Parameters" option to scan 11" by 17" portions of quad maps with the Howtek Scanmaster. The quad maps were scanned in color and stored as optimized color images Figure 4.).

2. **Quad Map Registration** - The scanned quad map images were registered to latitude / longitude geographic coordinates by means of MIPS "Prepare > Raster > Register > Manual" option. This option lets the user point to known geographic locations on the image, using the mouse, and then key in the geographic location in terms of latitude / longitude. In this case the 2.5 minute tick (fiducial) marks, visible on the quad map image, were identified (Figure 5.).

   Typically, a 4 or 6 point fit was employed and the resultant accuracies were within the tolerance of the displayed results - 1 second latitude / longitude (about 34 meters). Once 3 or more control points had been entered, MIPS was able to immediately display the geographic position of the cursor in lat. / lon. as it was dragged along the image. This could prove useful for immediate geographic location of point features on maps and images. At the conclusion of the Register routine, the transformation coefficients and associated control point lists were stored as part of the quad map file. These values remained available for later operations or for further refinement of the registration process, if so desired.

3. **Aerial Photograph Scanning** - Aerial photographs were scanned into MIPS using MIPS "Prepare > Raster > Scan > Parameters" option. This function allows the user to perform a fast, low

resolution, preliminary preview of the image so that final image resolution, size, and color qualities may be selected (Figure 6.). The available resolutions vary incrementally from 75 - 300 dpi. Scanned image sizes may range up to 11 by 17 inches. The quality and scale of the evaluated SAV aerial photographs was suitable for scanning 1280 H by 1024 V screen sized images at resolutions ranging from 120 - 200 dpi, with most images scanned at a resolution of 150 dpi. Once final scanning parameters were selected for the scanned photographs, the images were either scanned and written directly to the pc hard disk, or scanned, displayed, then written to the pc hard disk using the "Save / Load" functional key facility.

The system default for color scanning applies a logarithmic gamma correction to the scanned input color radiance values and then (based on the sampled color range) assigns 240 distinct color values to be used throughout the image. This worked very well for the Alexandria, VA, Mount Vernon, VA areas, considering the large number of colors assigned to urban areas outside the field of interest (Figure 7.). Attempts to improve upon the default color optimizing techniques by utilizing user selectable color transformation options were partly successful. Color separation and delineation of large SAV beds in mid-river were slightly improved. There is potential for refinement and progress here that requires further study. It is important to note that image acquisition operations can be controlled and optimized, since this permits optimal extraction of information from images whose features of interest have low contrast (either natural or resulting from problems in image acquisition).

Panchromatic positive contact prints and color positive contact film transparencies were also scanned into MIPS. Features in evaluated panchromatic photographs of the Alexandria, VA area and the Bloodsworth Island, MD area had high spatial and radiometric fidelity and SAV beds were easily identified by eye (Figures 8. and 9.).

Features in evaluated color positive contact transparencies had problems with color thresholding, as is evidenced by color contour plateaus radiating out from the center of the scanned image (Figure 10.). These features were not present on the original photographs and may have resulted from the relatively low contrast of these photographs:

Air Video - By virtue of image processing oriented design and use of standard computer graphics processing components, MIPS was able to easily digitize aerial images of SAV acquired by video camera. The use of this technique for remote sensing studies is described in Meisner (1986) and Sidle and Ziewitz (1990). For this study color, vertical, aerial video recordings of SAV beds located in nearshore regions of the lower York River, VA, taken on 26 October 1988, from altitudes of 670 and 1340 meters (2200 and 4400 feet), were evaluated. The images were recorded in flight on a standard 0.5 inch VHS video cassette tape. The MIPS workstation at the Virginia Council on the Environment was used for input of the video data.

Video data were entered into MIPS using a standard video cassette recorder (VCR) whose video signal cables were connected to the MIPS workstation. The MIPS "Prepare > Video > Capture" function was used to replay the video on a medium resolution color monitor, suitable for display of the standard television images produced by the video system. For video, 30 images per second are acquired. The Video function allows the user to select images for entry into the system by viewing recorded moving images on the monitor and capturing the desired image by means of the keyboard. Video may be processed as either black and white or color images (Figure 11.). The inherently low spatial resolution of digitized video images (512 H by 485 V) is offset by low acquisition cost per image and continuous coverage, making this medium well suited for low altitude, large scale photography. Acquisition of complete, detailed, low cost coverage of SAV beds may be enhanced by the use of aerial video images, as long as adequate ground control points are available in the video imagery for proper ground registration and map rectification of the resultant images.

4. **SAV Delineation** - SAV areas appearing on scanned images were typically clear and distinct. SAV was also the only feature being delineated in this study. Because of these factors, a decision was made to delineate SAV directly on the raster image and to transfer the delineated raster SAV outlines to vector coordinates in a subsequent step. This approach had the advantage of retaining the photograph image and SAV outline in one raster data set, ensuring that both would always be available for inspection and modification. The MIPS "Draw > Draw" functional key facility was used to delineate SAV areas as well as fixed geographic test areas appearing on high-res screen images of the scanned aerial photographs. The geographic test areas provided a basis for distinguishing systematic processing differences from individual photo-interpretive differences in comparisons of MIPS with VIMS SAV GIS and pc ARC-INFO. The Draw function enables the user to interactively color points, lines, or areas on displayed images, using the pc mouse as a "paintbrush". For outlining SAV areas, a "reserved" numerical color value, not present in any part of the displayed image, was chosen for the outline (in this case 254) and assigned a bright, contrasting color (yellow) (Figure 12.). Under this function, portions of the displayed image may be enlarged 2, 4, or 8 times while outlining, by means of a real-time, raster replication, zoom function.

   Errors detected during outlining were immediately corrected by pressing one of the mouse buttons. This had the effect of gradually erasing the most recent points entered. Once an area was complete, MIPS automatically closed (connected) the area and permitted the user to inspect it by panning and zooming throughout the image (Figure 13.). The user then had the option to accept, correct, or reject the resulting outline. At any time during the Draw function, outlined areas could be examined and modified as necessary. This was a very easy and natural tool to use, emulating the best elements of manual delineation of features on maps and photographs.

SAV beds were also delineated using an automated feature extraction routine operating under MIPS "Interpret > On-Screen > Feature Map". This function incorporates useful elements from manual and automated classification methods to produce a realistic identification of natural resource features (in this case SAV) (Figure 14.). This particular feature mapping routine is based on color and contiguity. In this case, the identified features (colored yellow on the screen) may be considered more as estimates of actual SAV plant cover within the bed area (plant and estuary bottom) than as estimates of the bed as a whole. This differentiation between SAV plat cover and bed area may be useful in growth and productivity analysis.

In addition to outlining or identifying SAV areas, evenly distributed known geographic points, appearing both in scanned images and quad maps of the area, were delineated by means of drawing overlying ticks or outlines on the raster image for later use in geographic transformations of images and derived vector data sets. Typically 6 to 10 control points were selected, e.g. road intersections, stream confluences, prominent shorelines, etc.

5. **Raster to Vector Processing** - The MIPS "Prepare > Raster > Rast -> Vect" suite of functions were used to transform SAV outline and delineated geographic ground control points from raster to vector format. The transformation was accomplished by running the following subfunctions under "Rast -> Vect":

   o "Threshold" - A raster image copy function that only copies cells within user selected values (in this case 254) and creates a "binary" raster image of outline and non-outline areas. This had the effect of copying only the SAV bed and geographic test area outlines and geographic ground control points to a temporary raster image.

   o "Define Type" - A function that creates polygon type lists for use in labeling polygons in the raster to vector conversion. Polygon type lists are stored as sub-objects of the raster file that are carried along throughout subsequent processing. In this case, labels were entered that corresponded to SAV beds or geographic test areas.

   o "Label Areas" - A function that assigns labels to polygons within thresholded raster images. Polygons are identified by the user via the mouse, with the appropriate label being selected from the polygon type list associated with the raster image. Like polygon type lists, polygon labels are also stored as sub-objects, carried along throughout subsequent processing.

- "Thin Raster" - A raster function that automatically operates on binary raster images to reduce point, line, and polygon outlines to widths of one raster cell, so that the data is suitable for conversion to screen coordinates. Output is stored in a temporary raster image file.

- "Auto-Line" - A function that automatically converts thinned raster data to vector data, based on relative screen coordinates ranging from 1 - 1280 horizontally, 1 - 1024 vertically. For SAV, the resultant vector data sets were quite small compared to their raster counterparts, as the SAV outlines made up a very small portion of the entire raster image (Figure 15.). It should be noted, however, that every raster cell was converted to vector coordinates by this function, regardless of its position in the outline. Further point reduction and smoothing was accomplished by MIPS "Thin-Vect" function.

The "Threshold", "Thin-Raster", and "Auto-Line" functions run automatically in a matter of minutes. Temporary files produced by threshold and thin-raster may be deleted once a vector file has been produced by "Auto-Line".

At this point in processing, the point, line, and polygon outlines in the derived vector data set may be modified by means of MIPS "Prepare > Vector > Edit Vector" suite of functions. The user can add, modify, or delete labels relating to vector features appearing on the high-res color monitor, by means of the mouse and keyboard. The labels are recorded as a sub-object in the resultant vector file and are carried along throughout subsequent processing as identifiers in statistical and output operations.

6. **Thinning of SAV Vector Data Sets** - The outlined SAV vector sets required additional "thinning" to reduce redundant points and to smooth outlines by eliminating artifacts resulting from their origin as rectangularly gridded raster cells. As, mentioned in Step 5. above, the MIPS "Auto-Line" function converted every raster cell to vector coordinates, regardless of its position. This resulted in many redundant points occurring on straight line or gradually curving line segments, in instances where only the end points or a few intermediate points were necessary to accurately describe the shape of the feature. Also, due to the discrete, rectilinear nature of the raster display, all non-horizontal, non-vertical lines or features appeared to have jagged, step-like edges ("jaggies"), as MIPS assigned the nearest rasters to approximate their shape.

   The MIPS "Prepare > Vector > Thin-Vect" function was used to interactively thin and smooth the vector data sets by selecting, via pc mouse, minimum allowable vector line lengths. The results were displayed in real-time over normal or enlarged displays of SAV vectors data sets. Jagged edges were eliminated by selecting minimum vector lengths greater than typical individual raster step lengths (Figure 16.). This function typically reduced the number of vector data points by 60 - 80 percent, while retaining the essential shapes of the outlines, eliminating jagged artifacts, and improving the overall appearance of the vectors (Figure 17.).

7. **Map Registration of SAV Vector Data Sets** - The MIPS "Prepare > Vector > Map Proj > Overlay" function was used to register the SAV vector sets (obtained in Steps 5. and 6. above) to a raster quad map of the area, with known geographic properties (obtained during quad map scanning and registration, Steps 1. and 2. above). The SAV vector data sets were capable of being displayed on registered raster images of scanned quad maps. The vector outline and points appeared as white or colored lines on the scanned map (Figure 18.). The pc mouse was used to "drag" or link ground control points appearing in the overlaid vector data set with those present in the screen image of the map (Figure 19.). Transformation options include "linear least-squares", "piecewise linear least-squares", and "polynomial least-squares" fit. As the selected ground control points on the SAV vector files were fairly evenly distributed throughout the image and as the photographs were nearly vertical, the linear least-squares transformation and the piecewise linear least squares transformation produced the most accurate fits between the vector and map data sets, as determined by visual inspections of the resultant screen images (Figure 20.). Control points could be added, modified, or deleted until an accurate fit was achieved. Upon exiting the function, the map transformation coefficients and control point lists were stored with the vector file as sub-objects for use in subsequent processing.

8. **Length and Area Measurements** - Currently, MIPS computes vector scale factors from calibrated linear distances entered on the source raster image rather than from transformation coefficients derived from the vector map registration process. In order to derive scale factors, the MIPS "Meas > Calipers" functional key facility was used to delineate known linear distances on the raster image that produced the vector data set. Geographic landmarks appearing on both quad map and image were identified and tagged with the cursor. The intervening distance, previously measured on the associated quad map, was entered into MIPS using the "Cali" sub-functional key. MIPS then computed a cell size for the image which was stored as a sub-object in both the raster and vector image data sets using the "SvSc" sub-functional key.

   Area measurements of SAV and test area vector polygons were made using the MIPS "Interpret > Vector > Polygon" function. This function used the cell size derived in "Meas > Cali" to compute and display areas of polygons selected via the mouse or compute (without displaying) areas of all polygons. Results were stored in readable American Standard for Character Information Interchange (ASCII) text files and included polygon number, perimeter, area, area to perimeter ratio, roughness, centroid locations, and polygon type label with measurements in user selected units.

9. **Export of Registered Vector Data Sets** - MIPS "Prepare > Export > Vector" suite of functions were used to "export" or transfer calibrated and labeled SAV polygon data sets to disk files in standard GIS data formats. This study employed both the "MOSS" option for exporting data in USFW&S MOSS "Export" format and the "ARC-INFO" option for exporting data in ESRI's ARC-INFO "Generate" format. MIPS accomplished this by applying map transformation coefficients, obtained during the vector registration process (Step 7. above), to the SAV vector data to transform the data to units of decimal degrees of longitude and latitude and then writing the data to file in standard character format. The SAV files in MOSS and ARC-INFO format were written to floppy diskettes for subsequent entry and display in the W&M / VIMS Bayplot mapping, station, and trackline plotting program and pc ARC-INFO GIS.

ARC-INFO Methodologies for MIPS Data Acquisition - Both the minicomputer and microcomputer versions of ESRI's ARC-INFO GIS support data conversion of MOSS Export and ARC-INFO Generate files. For this study, the microcomputer version, pc ARC-INFO, was employed using pc ARC-INFO workstations at W&M / VIMS. The "MOSSARC" command, operating under pc ARC-INFO's pc Data conversion suite of commands, and the "Generate" command, operating under pc ARC-INFO's Starter Kit suite of commands, were used to read the appropriate SAV files from floppy diskette files and perform the conversion from latitude / longitude based SAV vector file format to pc ARC-INFO vector file format (ESRI, 1989). The data were then transformed to Universal Transverse Mercator (UTM) coordinates, using pc ARC-INFO's "Projec" command, and plotted at a scale of 1:24,000 for comparison with the MIPS SAV and VIMS SAV data sets (Figure 21.).

SAV Coverage Data Collection Using MIPS - Preliminary analysis and evaluation of study areas suitable for SAV data collection and analysis using MIPS resulted in emphasis placed on the following study areas - the upper Potomac River in the vicinity of Alexandria, VA and Mount Vernon, VA and the middle reaches of the Chesapeake Bay in the vicinity of Bloodsworth Island, MD. The Alexandria, VA and Mount Vernon, VA sites were highly urbanized areas, with SAV species and distribution patterns typical of those found in the upper reaches of estuaries. The aerial photographs used for these areas were 9" by 9", 1:24,000, vertical, color, positive contact prints taken on 2 September 1987 for the annual SAV survey - photograph numbers: 129-4, 129-6, and 129-7. In addition, 9" by 9", 1:24,000, vertical, panchromatic (black and white), positive contact prints taken on 25 September 1987 used for comparison of color and panchromatic photographs - photograph numbers 130-04 and 130-05. The SAV was clearly discerned on these photographs both by eye and when scanned into MIPS in color and black and white. Ground control points used for map rectification of SAV coverage data for these areas consisted primarily of road intersections clearly visible on scanned quad maps and photographs of the sites.

The USGS Alexandria, VA - DC - MD, 1965 (Photorevised 1971, Photoinspected 1972), 7.5 minute (topographic), 1:24,000, paper base, quad map edition and the USGS Mount Vernon, VA - MD, 1966 (Photorevised 1971), 7.5 minute (topographic), 1:24,000, paper base, quad map edition were used in this area for geo-referencing and map rectification. The paper quad map products were selected due to their suitability for scanning into MIPS and because shrinkage and expansion due to humidity posed no difficulties for MIPS since positional adjustments were made for these factors when resultant digital image data were mathematically rectified to standard map base. The analysis of 1987 SAV distribution conducted by W&M / VIMS using the VIMS SAV GIS and used for comparison in this study employed the USGS Alexandria, VA - DC - MD, 1965 (Photorevised 1979), 7.5 minute (topographic), 1:24,000, mylar base quad map edition (Figure 22.) and the USGS Mount Vernon, VA - MD, 1966 (Photorevised 1983, Bathymetry Added 1982), 7.5 minute (topographic - bathymetric), 1:24,000, mylar base, quad map edition (Figure 23.) as base maps for manual delineation of SAV beds (Orth et. al, 1989).

The Bloodsworth Island, MD site was a U.S. Naval Reservation wilderness area located in the middle of the Chesapeake Bay. SAV species and distributions patterns were typical of those found in more open, haline regions, with beds occurring in protected embayments along the shore, and in large shallow flats located between several small islands to the south. The aerial photographs used for Bloodsworth Island were 9" by 9", 1:24,000, vertical, panchromatic, positive contact prints taken on 5 October 1987 for the annual SAV survey - photograph numbers 06-05, 06-03, 06-02, 05-01, and 05-03. Due to favorable environmental conditions and the proper choice of film and camera type, areas with SAV were clearly discernable on both the photographs and scanned images of the photographs. Ground control points for this area consisted primarily of stream confluences, natural features within the island, and promenant shoreline features.

The USGS Bloodsworth Island, MD, 1973, 7.5 minute, orthophotomap (topographic), 1:24,000, paper base, quad map edition was used in this area for map input, geo-referencing, and map rectification. SAV beds analyzed in the W&M / VIMS study of 1987 SAV distribution were delineated on the USGS Bloodsworth Island, MD, 1973, 7.5 minute, orthophotomap (topographic), 1:24,000, mylar base, quad map edition (Figure 24.).

Results of preliminary analysis of another study site, located in the lower York River, determined that further analysis of this area would add little of significance to the evaluation. Upon review of aerial photographs of the area taken on 28 June 1987 - photograph numbers 93-08 and 95-04, it was evident that the surface waters in certain critical locations were noticeably turbid, and that these unfavorable environmental conditions would preclude detection of known underlying SAV beds, complicating an essential element of the evaluation. In addition, this area had little potential for offering additional significant information to the study, as the photographs were color positive contact prints (evaluated in the Alexandria, VA, Mount Vernon, VA areas) and the area was rural, but with sufficient numbers of roads and natural features for adequate selection of ground control points.

The Alexandria, VA, Mount Vernon, VA and Bloodsworth Island, MD study areas spanned the range of resources and environments that would reasonably be encountered in SAV distribution and abundance studies. Accordingly, these areas were sufficient and appropriate for further analysis and evaluation.

It should be noted that it was during the processing of the study areas that the methodologies for SAV data collection using MIPS were developed and refined. Thus the site evaluation process was valuable in providing a practical model on which to develop methods and techniques.

Intermediate data sets and plots produced during processing of each area included:

- o Scanned quad maps of each study area, used for map rectification.
- o Scanned raster images of aerial photographs in each area, with SAV coverage outlined in a unique color value (cover figure).
- o Plots of SAV bed and geographic test polygons and ground control points (Figures 25. - 32.).
- o Vector coordinate files containing edited SAV coverage files, registered to a geographic coordinate system.
- o Statistic files containing area and length measurements for each SAV and test area polygon.

The final MIPS data products for each scanned aerial photograph were MOSS Export and pc ARC-INFO Generate files containing SAV outlines in longitude / latitude units. As the files were written in ASCII format, the files for each area were post-processed at W&M / VIMS using a standard text editing program to concatenate the individual vector files produced for each aerial photograph into one large master file for the area.

Further processing and editing of SAV coverage data, such as connecting SAV coverage areas that overlap from one vector file to the next, could be accomplished using ARC-INFO. ARC-INFO would be an appropriate system to produce complete SAV coverage data sets for areas of quad size dimensions or larger.

Importation of MIPS SAV Coverages into ARC-INFO - MIPS SAV coverage data in MOSS Export and ARC-INFO Generate format were imported into pc ARC-INFO for further processing and analysis as described in the "ARC-INFO Methodologies for MIPS Data Acquisition Section" section above. For ease of processing, the SAV vector data units were converted to the UTM coordinate system, which has the advantage of being a map coordinate system with equal distance units along the orthoganal north / south axes. The SAV coverage data for each study area were plotted at a scale of 1:24,000 for comparisons with the SAV coverages produced by MIPS before entry into pc ARC-INFO, and similar SAV coverage data produced by the VIMS SAV GIS.

Comparisons of MIPS, ARC-INFO, and VIMS SAV GIS - Comparisons of MIPS, ARC-INFO, and VIMS SAV GIS were conducted by comparing the procedural processes by which SAV coverage data were collected by the three systems, and by comparing the qualitative SAV coverage plots and quantitative SAV aerial statistics produced by each system. MIPS features and processing capabilities have been described in detail elsewhere in this report. Summary features of the VIMS SAV GIS and ARC-INFO are given below.

Regarding procedural processing, the VIMS SAV GIS was in many respects both the least and most flexible system. This system relies on manual transfer of SAV coverage data from aerial photographs to 1:24,000 mylar quad maps (Orth, R. J., K. Moore, and R. Byrne, 1987, Orth et. al, 1987, Orth et. al, 1989). To facilitate the transfer of data from photograph to map, vertical aerial photographs of nominal scale 1:24,000 have been used as the input photographic medium. Photography at this scale has the advantage of closely approximating the scale of the base quad maps, so that SAV features may be traced directly onto maps by simple manual overlaying methods. SAV beds extending from one photograph or map to the next, may be accommodated by manually registering the adjacent photographs or maps until a satisfactory fit is achieved, then tracing the associated SAV features onto the base quad map.

Selecting a scale of 1:24,000 for aerial photographs limits the number of photographs necessary to cover large areas, such as the Chesapeake Bay, to manageable numbers, and ensures that sufficient ground control information will be present in each photograph to permit map registration. In order to obtain 1:24,000 photographs with proper geometric properties, the photographs must be taken at altitudes of 3660 meters (12,000 feet). At this altitude, intervening atmospheric haze between water surface and aircraft often becomes a limiting factor, especially during summer months when SAV is photographed. Larger scale photographs, taken at lower altitudes would have the benefit of reducing summer haze conditions to acceptable levels, while at the same time providing more detailed information on SAV. At present, however the only way the VIMS SAV GIS can accommodate larger scale photographs is to employ a laborious, optical tracing system, such as the Bausch and Lomb Zoom Transfer Scope (ZTS) or by selecting base maps at scales similar to the larger scale photographs.

The lack of interactive visual image feedback during the process of digital data entry of SAV outline data into the VIMS SAV GIS, necessitated implementation of a quality control process which requires three entries of each SAV outline be made, in order to identify and eliminate spurious data points by inter-comparisons of the triplicate outlines. Once the data is in an edited digital vector format, the VIMS SAV GIS performs well. It is, however, dependent on slower, more traditional methods of data display for review and editing processes. Pen plots are made of the digitized SAV beds to ensure that they were entered correctly. The custom nature of the software enables it to be tailored to meet individual research needs and requirements. A marked disadvantage of the VIMS SAV GIS software is that a knowledgeable programmer is required to maintain, modify, or improve the system. There is little chance that this specialized system could approach the degree of sophistication offered by commercially available systems, that are able to spread their development costs over a large user base. None the less, given the available resources, the VIMS SAV GIS has been able to produce useful and appropriate SAV distribution and abundance data annually.

ARC-INFO and its pc subset, pc ARC-INFO, have traditionally focussed their efforts on analysis and processing of environmental coverage data, whose type and extent have previously been determined. In this respect, it is similar to the automated elements of the VIMS SAV GIS. ARC-INFO does, however, have the capability of entering, via digitizing tablet, environmental coverage data directly from source photography. The resultant vector data can be rectified to map coordinate systems by map rectification routines, similar to those employed by MIPS. ARC-INFO does not provide the level of interactive feedback during digitizing that MIPS does. Rather, it provides a two dimensional, real-time display of the digitized features, as opposed to the scanned image with digitized features overlayed, as in MIPS. ARC-INFO's strengths lie in its abilities to combine, process, and analyze a variety of pre-determined environmental data sets. It has been employed by the EPA Chesapeake Bay Liaison Office (CBLO), Annapolis, MD as the system to process SAV coverage data as well as other Chesapeake Bay environmental data sets. It is also the system used to process and analyze Virginia EcoMAP data at the Virginia Department of Conservation and Historic Resources, Richmond, VA.

SAV coverage data for the Alexandria, VA, Mount Vernon, VA, and Bloodsworth, MD areas produced by the VIMS SAV GIS, pc ARC-INFO, and MIPS were plotted at W&M / VIMS at a scale of 1:24000 and compared for similarity (Figures 33. and 34.). It should be mentioned that for these small areas, positional differences arising due to use of UTM or mercator map projections did not adversely impact map comparisons. In general, the plotted outlines overlayed well, with differences arising mainly from initial photo-interpretive factors, rather than systematic processing errors. Most important, the fixed, ground control points identified in MIPS and transferred over to pc ARC-INFO had a high degree of correspondence between the individual plots and their mapped locations as determined by the master, mylar quad maps, with average positional differences on the order of 30 meters.

Areal statistics compiled for 1987 SAV beds in the Alexandria, VA, Mount Vernon, VA, and Bloodsworth Island, MD areas using VIMS SAV GIS, MIPS, and pc ARC-INFO have been compared using standard statistical comparison routines run using the W&M / VIMS Prime Computer version of the SPSS statistical program (SPSS, 1988). In order to isolate systematic errors from photo-interpretive differences, areal statistics for a number of known geographic test areas, visible on both maps and aerial photographs, were analyzed (Figures 25. - 32.). Areal statistics for these sites were also computed using the VIMS SAV GIS. Since geographic test area outlines were distinct and unambiguous, areal differences between MIPS, VIMS SAV GIS, and pc ARC-INFO for these sites related to systematic processing errors (map rectification errors, numerical errors, etc.) as opposed to differences in placement of SAV bed boundaries, related to individual photo-interpretive judgement and skill.

Areal data for 1987 SAV beds and geographic test areas in the study sites computed by MIPS, VIMS SAV GIS, and pc ARC-INFO are given in Table 1. Comparisons between areas measured by the three systems were produced by deriving both absolute and relative differences between each associated area pair as follows (Note: subtraction (-) and division (/)):

o VIMS and MIPS comparison:

- o Absolute Difference: absolute value ((VIMS area) - (MIPS area)).

- o Relative Difference: absolute value ((VIMS area) - (MIPS area)) / (VIMS area).

o VIMS and pc ARC-INFO (ARC) comparison:

- o Absolute Difference: absolute value ((VIMS area) - (ARC area)).

- o Relative Difference: absolute value ((VIMS area) - (ARC area)) / (VIMS area).

o MIPS and pc ARC-INFO (ARC) comparison:

- o Absolute Difference: absolute value ((MIPS area) - (ARC area)).

- o Relative Difference: absolute value ((MIPS area) - (ARC area)) / (MIPS area).

Standard statistical measurements (mean, standard deviation, and correlation coefficients) were then computed (Table 2. and 3.).

Because of the large range in individual area sizes (thousands to millions of square meters), the results of statistical measurements of absolute area differences are not as easily interpreted as are those of relative area differences. For the geographic test areas for all three systems, mean absolute differences ranged from 10,151 - 17,250 square meters, mean relative differences ranged from 2 to 5 percent, with associated standard deviations ranging from 1 to 3 percent. For SAV bed areas, mean absolute difference for the MIPS and pc ARC-INFO comparison was 6,272 square meters; mean relative difference for the MIPS and pc ARC-INFO comparison was 2 percent, with standard deviation of 1 percent. This is consistent with the results for the geographic test areas, as area polygon coordinate sets for both test and SAV areas were generated by MIPS. Mean absolute differences for the SAV bed comparisons of VIMS with MIPS and VIMS with pc ARC-INFO were 23,320 and 27,648 square meters respectively; mean relative differences for SAV bed comparisons were 30 and 31 percent respectively, with associated standard deviations of 29 percent.

Scatterplots of VIMS and MIPS area measurements were constructed for both geographic test areas and SAV bed areas (Figures 35. and 36). The test areas displayed a high degree of linearity and association. The SAV bed areas also displayed high levels of association, with greatest similarity in regions less than 10,000 or greater than 100,000 square meters, and greatest differences in the 10,000 - 100,000 square meter range. Correlation coefficients were computed for test areas and SAV bed areas (Table 3.) The test area correlation coefficient was 0.999 and the SAV bed area correlation coefficient was 0.998, both at the 0.001 significance level.

Results of Test and Evaluation Trials of MIPS - In summary, MIPS was easy to use, being menu driven with appropriate pop-up menus to direct one in a logical hierarchical manner through various operations. Aerial photographs and maps were easily scanned into MIPS in either color or black and white. Rectification of aerial photographs and maps to geographic coordinates (latitude / longitude) was accomplished with accuracies on the order of 1 second latitude / longitude (34 meters). The resolution and color fidelity of the image scanner was such that all SAV beds in the aerial photographs were easily identified.

As SAV was the sole coverage feature being extracted for this study, MIPS interactive manual outlining functions were employed. The 1280 H X 1024 V high resolution color monitor made the manual delineation of SAV beds with a mouse extremely easy. If a number of different features were to be identified and extracted from digital images, then MIPS automated feature classification routines would have combined the best elements of automated and interactive systems, maximizing the likelihood of correct feature identification. Conversion of grid-based raster boundary data to corresponding vector data was fairly straightforward and automatic, resulting in optimal numbers of geo-referenced, coordinate pairs to accurately delineate SAV polygons. Computation of SAV bed and geographic test area statistics was performed with results output to ASCII text tiles. Export of SAV vector polygon files in standard MOSS or ARC-INFO formats was accomplished, the output medium being floppy disk.

Both color and black and white photographs provided adequate information for detection and delineation of SAV. Environmental conditions, such as atmospheric and water clarity, tidal stage, presence of surface waves, sun glint, and biological conditions, such as peak growing season, appeared to be dominant factors governing the detection of SAV on aerial photographs. The urban and suburban areas in the Alexandria, VA and Mount Vernon, VA study sites had many geographically fixed features that appeared on both aerial photographs and base maps, necessary for use as ground control points in map rectification routines. Surprisingly, the wilderness areas of Bloodsworth Island, MD also provided sufficient numbers of geographically fixed natural features for adequate map registration. The critical factor appeared to be the amount and relative location of land features in the photographs, regardless of state of development.

Comparisons of SAV areas identified both by MIPS and conventional photo-interpretive methods at W&M / VIMS have been conducted, by overlaying corresponding 1:24000 plots on same scale mylar quad maps containing manually photo-interpreted outlines of identical SAV beds. The SAV beds identified by MIPS, and the ground control points used in geographic transformations, conformed with those found on VIMS SAV GIS plots and USGS mylar base maps, with average point positional differences on the order of 30 meters. Statistical analysis of geographic test areas and SAV bed areas showed high degrees of association between the VIMS SAV GIS and MIPS, with correlation coefficients of 0.999 for test areas and 0.998 for SAV bed areas. Relative differences between VIMS SAV GIS, MIPS, and pc ARC-INFO, identified systematic differences (test areas) on the order of 5 percent, and systematic plus photo-interpretive differences (SAV bed areas) on the order of 30 - 31 percent.

Processing times and level of personnel expertise required for MIPS identification and extraction of SAV distribution and abundance data appeared to be comparable to those of the VIMS SAV GIS. Time savings occurred primarily in SAV delineation and registration / rectification of aerial photographs to base maps. For MIPS, the aerial photograph - map registration process is independent of scale, as automated analytical fitting routines are used in the registration process. As long as features of interest are discernable on the photographs and / or maps, the scale of the source photographs and maps may differ significantly. This feature facilitates the selection of optimal scales for aerial photographs by eliminating requirements for photographs and map to be at similar scales. Other more appropriate criteria, such as minimum ground resolution, maximum photographic coverage, and optimal atmospheric conditions, can become deciding factors when determining aerial photographic scale.

As MIPS typically operates on an image by image basis, each scanned aerial photograph or map was, for the most part, processed separately. MIPS is able to construct image or map mosaics by means of MIPS "Prepare > Raster > Merge > Mosaic > Mosaic" function. This function requires that each image be geo-referenced and transformed to a common geographic reference framework, using a linear or polynomial resampling process, based on image ground control points delineated in a map registration process. The creation of mosaic data sets is somewhat lengthy, due to the large number of calculations involved (e.g MicroImages estimates construction of a mosaic of a full 7.5 minute USGS quad map, from scans of each quadrant, would take about 1 hour). The geometry of MIPS mosaic images would most likely be superior to those of manually produced mosaic images. For this study, the decision was made to treat each photograph and map as a separate entity, and to resolve problems of SAV overlap and contiguity with a coordinate based GIS, such as ARC-INFO.

Throughout the study, it was apparent that MIPS was designed for natural resource applications. Photographs and maps were scanned at resolutions appropriate for feature identification. Image and map operations were oriented towards the research needs and methods of photographic interpreters, geographers, and naturalists. This was very encouraging as it reflects a commitment by MIPS to direct their efforts towards the field of natural resource research and management.

Section 3.

Discussion of Results

Feasibility - Traditionally, scientific and management projects have been constrained and directed in part by available data and associated data analysis and processing resources. MIPS and other modern map and geographic information systems have the potential for expanding these analytical resources, thereby providing opportunities for design and application of less constrained studies, better able to meet current research and management needs. "Feasibility", therefore, has been treated as a somewhat relative concept, in that MIPS's powerful analytical processing tools make the system capable of performing both current types of SAV analysis and more advanced analysis, currently not feasible with existing processing resources at hand.

The study results demonstrate that MIPS was able to accurately extract SAV distribution and abundance information from source aerial photographic data, as was previously done with the VIMS SAV GIS. Due to the fact that MIPS supports delineation of SAV directly on scanned images and rectifies the resultant SAV outlines to map coordinates by means of scale-independent, analytical transformation routines, very accurate and complete SAV outlines are produced, without the constraints of scale involved with the manual tracing of spatial data from image to map base, as is the case with the VIMS SAV GIS. With regards to areal measurements using MIPS, the comparison of pc ARC-INFO with VIMS SAV GIS for known geographic test areas produced the closest agreements. This suggests that MIPS map rectification process (used to produce input polygons to pc ARC-INFO) results in more accurate geographic fits and areal measurements than those resulting the process which employs MIPS "Meas > Cali" function to determine cell scale from a known linear distance input by the user.

The feasibility of using MIPS for large area, comprehensive studies, involving the processing of hundreds or thousands of images, as is the case with periodic studies of the Chesapeake Bay and its tributaries, remains undetermined at present. Currently, areas covered by 7.5 minute USGS quad maps, are used as basic geographic reference units in the VIMS SAV GIS. On the average, complete SAV processing of a quad map size area containing fairly extensive SAV beds, using MIPS, would take one working day, from initial input of source photography to production of digital SAV vector outlines and associated distribution, abundance, species, and location information. Given that Chesapeake Bay shoreline regions encompass 176 USGS quad maps, of those 176 quad maps areas, 100 have SAV, and most of those 100 areas have SAV in relatively small amounts, it is estimated that 100 days or less would be required to process these areas using one MIPS workstation.

The study also showed that MIPS was able to easily process aerial photographs and maps of different scales. This feature would make it feasible to tailor the scale of source photography to individual study requirements, without being tied down to particular scales dictated by considerations of manual transfer of photographic data to base maps. For SAV, this opens the possibility of using lower altitude, larger scale, more economical photography than currently used, in order to compensate for adverse atmospheric haze conditions encountered during periods of peak standing crop (typically June - October, species dependent).

The study demonstrated that MIPS can process aerial video images recorded on video tape during flight and replayed into MIPS via a VCR. The relatively low cost of video camera, recording, and processing equipment, and the complete along-track coverage provided by video systems, makes low altitude, detailed, video studies feasible using MIPS, provided images have sufficient spatial data to meet geographic registration requirements.

As MIPS is based on popular microcomputer hardware and software, it is reasonable to expect that MIPS processing capabilities will improve over time as computer technology advances, as has been the case with ERDAS and ARC-INFO. As more powerful components become available, processing "snags" and performance problems may improve as a result of incorporation of advanced, improved components. If a commitment has been made to incorporate MIPS into areas of geographic data processing, then component upgrades may be all that is required to take advantage of advanced processing features. Granted, this is conjectural, however the explosive growth and development in the microcomputer field, and advances made in geographic processing systems in the past few years, lend credence to this supposition. In any event, individualized, non-generic processing systems, such as the VIMS SAV GIS, have little likelihood of advancing beyond their present state of development, without considerable expenditures of time, effort, and other resources; costs that are borne solely by the users of such systems.

Costs - Costs can be broken down into three broad categories:

- System acquisition costs.
- Operating costs.
- Maintenance costs.

System acquisition costs range from $16,000 to $40,000 per MIPS workstation. Essential components required for processing of aerial photographic or video SAV data and their related costs (including device specific MIPS software) are:

- High resolution, 1280 H by 1024 V, workstation - $16,200.
- High resolution, 11" by 17", photographic / map scanner - $7,900.
- High capacity mass storage device for off-line storage of image data:
    - 100 Mbyte plus tape cartridge unit - $1,500.

      or,
    - 800 Mbyte plus optical disk drive unit - $5,000.
- Color plotter:
    - High resolution for image plotting - $9,520.
    - Low resolution for image plotting - $1,800.
- Video image acquisition system:
    - Video camera system - $3,200.
    - Graphics board - $3,500.
    - Color monitor - $1,000.

- VCR (super VHS, with red, green, blue (RGB) inputs - $1,000.

Additional MIPS units would most likely only require the high-res workstation, with the necessary circuit boards to support attachment of external peripheral devices, such as scanners and plotters. The most essential external device, apart from the MIPS workstation itself, would be the high-res photographic / map scanner, which would be in constant use in large studies that depend on scanned photographic data for image input, such as Chesapeake Bay SAV studies.

Operating costs for MIPS would tend to be application dependent, varying with individual study requirements. Critical considerations are the level of spatial resolution and accuracy required to achieve desired results, the number of different features under analysis, and the geographic extent of the study. In this regard, MIPS processes image data in a standardized manner, producing accurate feature and geographic information. It is not as amenable to modification and easing of accuracy constraints, in favor of operational considerations, as is the case with manual systems, when qualitative, as opposed to quantitative, information is sought. For example, MIPS processing of 1:24,000 SAV imagery would require about the same level of effort, would produce results of about the same accuracy, regardless of relaxation of study requirements. This may present problems when MIPS is unable to take full advantage of manual "short cuts", such as rapid construction of image or map mosaics for analysis of features extending across borders, and must proceed in a more time consuming, standard fashion.

For large study areas, such as the Chesapeake Bay, estimated operating costs using MIPS are unknown. The sheer volume of data and the many intertwined and concurrent operations that are currently managed by the VIMS SAV GIS, may prove problematic for MIPS. Unexpected bottlenecks or breakthroughs could occur using MIPS in such an application. Typically, processing and component design for such studies evolve and develop until satisfactory results are achieved, given the available needs and resources.

Maintenance costs for MIPS are currently $800 per year for software maintenance. This includes quarterly updates and improvements to the software, correction of problems ("bugs") when possible, and telephone consultation with the staff at MIPS. Hardware maintenance costs are covered under the manufacturers' warranties and then must be borne by the user. The evaluated equipment at Salisbury State and Virginia Council on the Environment had reasonably good records of reliability. Typical annual hardware maintenance contracts run about 10 percent of product purchase price.

Quality - With regard to MIPS, considerations of quality apply to the system itself and resultant products. MIPS software is well designed and efficient. It is written in the "C" programming language, which was designed by American Telephone and Telegraph (AT&T) to support high level, interactive, screen-oriented operations. "C" has become a popular language, widely used for intensive, interactive processing, such as imaging or graphics applications. MIPS software is modular, based on a variety of task specific programs or routines. This design enables modules to be corrected or improved with minimal effect on other modules or larger routines that utilize them. Based on fairly extensive trials of MIPS, the software is a well designed, quality product.

MIPS hardware is manufactured and marketed by third parties for imaging, graphics, scientific, and business applications. The user has a great deal of latitude in selecting the generic pc-AT microcomputer with regards price, performance, and quality. With regard to peripheral devices, the selection narrows to the smaller set of devices supported by MIPS. The graphics boards supported by MIPS, such as Presto, and AT&T's Targa, are popular in computer graphics / imaging and appear to be fairly reliable. The Howtek Scanmaster is not as well known, but its performance during the evaluations was impressive and flawless. It appears to be a well designed, rugged device. Performance and quality of other peripherals, such as the 35 mm slide scanner, color printer, and optical disk drives have been harder to determine. The slide scanner will always be limited by the inherent quality of the slide, and thus its performance is difficult to ascertain, without in-depth analysis of input slide quality. Research and development in the popular areas of color printing and optical mass storage devices is still being driven by the need to produce systems that meet user requirements. For color this amounts to high resolution (300 - 400 dpi), low cost, real-time color copies. For optical storage, the requirements are for high capacity (800 plus Mbytes), rapid access, read / write devices. Currently these requirements have been only partially met. Economical color printers have only marginally met the requirement for high spatial resolution, and economical optical disk drives have only become available within the last year.

Suitability and Portability to Other Geographic Systems - MicroImages designed MIPS primarily for entry and analysis of geographic spatial data and exchange of geographic data between popular geographic processing / information systems. To that end, MIPS supports third party raster formats (ERDAS, GRASS, IDIMS, ELAS, TERRA-MAR, DTM, DEM, TARGA, TIFF, SPOT, LANDSAT, etc.), vector formats (MOSS, ARC-INFO, DLG, etc.), and computer aided design (CAD) formats (AutoCAD, VersaCAD, and CADkey). During the evaluation, MIPS produced MOSS and ARC-INFO files that were easily entered into a pc ARC-INFO workstation by means of floppy disks. The MIPS produced vector files imported into pc ARC-INFO worked well, and data plots produced by pc ARC-INFO corresponded well with the MIPS originals. All indications are that MIPS can and will produce data suitable for use on other geographic systems.

Source Data Requirements - MIPS provides a great deal of flexibility in the selection of source photographic or video data. The resolving power of the Howtek Scanmaster is comparable to that of the un-aided human eye. Accordingly, photographs that are amenable to direct visual interpretation are also suitable data sources for the scanner. The Howtek Scanmaster worked well with positive photographic contact prints but had problems with color thresholding when using color positive photographic transparencies. Utilization of separate storage for each primary color, as opposed to color optimization as was done routinely in the evaluation, may alleviate this problem. As designed, however, the Scanmaster can only accept 8.5 inch wide transparencies, and this excludes conventional 9 inch wide aerial photographic transparencies, unless the film has been physically trimmed. MIPS has recently announced support for a new flatbed scanner that will support transparencies in a full 11" by 17" mode, with 300 dpi or greater spatial resolution. Incorporation of this device into MIPS should greatly facilitate film transparency data input.

For SAV, atmospheric conditions, spatial resolution, and water clarity are controlling factors in the quality and usefulness of acquired SAV photography. During periods of peak SAV growth in summer, haze becomes a limiting factor in the selection of suitable conditions for the acquisition of SAV photography. As summer haze is fairly uniformly distributed in lower altitudes and is not concentrated just above the water, like surface fog, adverse haze effects can be reduced by lowering flight altitude, thereby reducing the atmosphere path length between water surface and aircraft. With conventional aerial camera systems, such as those currently used for acquisition of SAV aerial photography in Chesapeake Bay, reduction in flight altitude results in enlargement of photographic scale. The VIMS SAV GIS relies on photography and base maps at similar scales, in this case 1:24,000. If significantly different map and photographic scales are employed, a manual, optical transfer device, such as Bausch and Lomb's ZTS, must be used to accurately transfer features from photographs to maps. This is a time consuming and laborious process, and has not been considered feasible for past SAV studies.

On the other hand, MIPS, by virtue of its independence from base map scale, facilitates selection of optimal aircraft altitude as a means of reducing the effects of adverse atmospheric conditions. aerial photographic scale to meet requirements of each particular study. By the same token, MIPS supports selection of optimal photographic scale for each particular application. Controlling factors in the determination of scale of source photography are coverage extent, number of source images required, acquisition / processing costs, and available resources. MIPS facilitates the utilization of historical aerial photography by accommodating a variety of scales and film formats in individual studies.

Interpretation of Final Mapping Product - MIPS is capable of producing a variety of final mapping products, ranging from vector outlines of coverage data, to critical area statistics, to archived photographs and maps for use in environmental data management systems or periodic geographic analysis. Initial, intermediate, and final mapping data sets produced by MIPS were easily interpreted, as they were always presented in a two-dimensional image or graphical format on the high-res monitor. In fact, MIPS has a distinct advantage over systems that primarily display character data in the course of operation. With MIPS, the spatial characteristics of the data displayed on the high-res monitor assist in identifying the data set and the stage of processing associated with it.

MIPS is very amenable to corrections and modifications of the final mapping products. This is especially true, when production of the final product involves a number of steps, as desired adjustments may affect only a few steps, and intermediate data sets and routines developed during unaffected processing steps may be re-deployed in construction of revised products with little additional intervention.

Relative areal differences between VIMS SAV GIS, MIPS, and pc ARC-INFO, identified systematic differences (test areas) on the order of 5 percent, and systematic plus photo-interpretive differences (SAV bed areas) on the order of 30 - 31 percent. Systematic differences, therefore, accounted for 13 - 17 percent of the areal differences, with individual photo-interpretive differences accounting for the remaining 83 - 87 percent of the observed areal differences among the three systems.

Usefulness of Final Mapping Product - In the case of SAV, the final mapping products are geo-based, SAV outlines with associated distribution, abundance, species, date, and other specific information, in a format amenable to analysis and interpretation by the user and other interested agencies. These data are used in assessment of the vitality of SAV based on distribution and abundance, and its variability over time and space. These assessments are critical in formulating natural resource management and protection programs in estuarine areas.

In a more general context, the digital spatial data acquired and processed by MIPS in the course of environmental studies, such as SAV distribution and abundance analysis, can be regarded as "final mapping products" also. Spatial data sets that will be used in future studies, such as scanned USGS quad maps used in map rectification, may be written to an off-line mass storage device (cartridge tape or optical disk) for re-use in future studies. The use of previously prepared digital data sets, whether created by the user or third parties, could result in significant savings in study design and processing costs.

Section 4.

Conclusions

This feasibility study has demonstrated that MIPS is capable of being used as a device for accurate collection and display of information on the distribution and abundance of SAV from aerial photographs. Systematic areal differences between MIPS, VIMS SAV GIS, and pc ARC-INFO for similar geographic test areas were small, on the order of 5 percent. Comparisons of areal statistics for SAV beds served to determine combined systematic and individual photo-interpretive differences. The combined differences were on the order of 30 - 31 percent. Systematic differences, therefore, accounted for 13 - 17 percent of the areal differences, with individual photo-interpretive differences accounting for the remaining 83 - 87 percent of the observed areal differences among the three systems. This indicates that most of the areal differences can be attributed to individual photo-interpretive skill and judgement, and supports the conclusion that a skilled SAV photo-interpreter would be able to produce accurate and consistent SAV areal statistics using MIPS.

MIPS offers many advantages over current systems used for processing and analyzing SAV data. MIPS supports on-screen delineation of SAV, thereby eliminating the need for tracing SAV outlines on transparent or translucent base maps. Map rectification procedures used in MIPS operate independently of photograph and map scale, making MIPS amenable to analysis of photographic data at a variety of scales. For SAV, this scale independent feature provides a great deal of flexibility in planning and execution of aerial photographic surveys by broadening the range of available flight altitudes, so that adjustments can be made to compensate for adverse haze effects experienced during summer periods of peak SAV growth. MIPS's scale independence also supports incorporation in studies of historical photography at a variety of scales.

Intermediate data sets produced by MIPS, such as scanned maps and aerial photographs, may be stored for future use, thus reducing processing time and effort in periodic or similar studies.

MIPS also offers the prospects of potential benefits accruing from periodic updates and improvements by MicroImages that are included in software maintenance agreements. Third party geographic data sets are also amenable to incorporation in MIPS for use in particular geographic applications. Some of these data sets are in the public domain, such as USGS DLG data (shorelines, transportation networks, rivers / streams data, etc.), and thus MIPS provides the user a means of accessing and utilizing useful, economical data sets.

MIPS costs in terms of software and hardware are in line with other similar microcomputer systems. Its reliance on pc components is appropriate, as this type of image / GIS work is typically done at a one user workstation, and no particular advantage is gained by networking to a distributive processing system, such as a minicomputer. The use of pc components allows MicroImages to keep development costs to a minimum, while at the same time taking advantage of a very broad-based, rapidly developing market.

The construction of photographic and map mosaics using MIPS may present difficulties when used in large, comprehensive studies with regard to the amount of data processing and storage associated with this operation. Mosaics are useful when natural features extend beyond the boundaries of photographs or maps, or when artifacts, such as sun glint, preclude delineation of features in one of a series of overlapping photographs. Manual construction of mosaics is fairly straightforward and rapid, as photographs are aligned by eye and overlayed by hand until an adequate composite fit is achieved. Typically, there is some mismatch from one photograph to the next, but this is usually negligible. Automatic, analytical construction of mosaics using MIPS requires geo-referencing and map transformation of each component image. The creation of resampled mosaic data sets is relatively lengthy, due to the large number of calculations involved. The geometry and map accuracy of MIPS mosaic images would most likely be superior to those of manually produced mosaic images. However, the extra time, storage requirements, and associated costs of MIPS mosaic construction may make this process unfeasible when dealing with large numbers of photographs.

Image storage requirements may present some difficulties, when using MIPS for large, comprehensive studies, such as SAV inventories in Chesapeake Bay. The current inventory requires the acquisition and processing of about 2,000 aerial photographs, at a scale of 1:24,000, and taken at 3660 meters (12,000 feet). At half the altitude, 3 to 4 times more photographs would be required. For optimized color images, approximately 1 Mbyte of storage is required per image. Thus, if all the scanned images are to be stored, 2,000 plus Mbytes of storage would be required. This would require three 800 Mbyte optical disks. For SAV inventories, the final products are SAV coverage outlines, statistics, and associated information, as opposed to processed images. Digital image storage requirements would therefore relate to storage of permanent image data, such as scanned and rectified quad maps, and storage of temporary image data, such as scanned photographs currently in the process of SAV delineation. Whereas, it may be appropriate to store permanent image data on either erasable or "write-once" optical media, it would be more economical to store temporary image data on eraseable media, such as erasable optical disks, magnetic hard disks, or magnetic tape cartridges, that could be used again for the storage of subsequent data.

MIPS may present certain "bottlenecks" in the processing of large data sets, as processing operations are centered on each particular workstation, and not distributed for multi-user use. This presents little difficulty when all operations are done serially for each image or area. If, however, operations are to be done in parallel, with a large set of images scanned and processed at once, then corresponding amounts of temporary image storage capacity must be available. For example, SAV delineation requires that a highly trained and experienced individual perform the actual coverage delineation. To make optimal use of this person's time, results of all prior processing performed by other individuals must be available before delineation begins, and results of delineation must be stored for use by others in subsequent processing steps. Multiple MIPS workstations would facilitate workflow by allowing two or more processing functions to occur simultaneously. The additional workstations would only require those peripherals necessary to conduct their particular function.

There are situations which present particular problems with regards to data collection and processing, and ideal solutions may not yet be available. Delineation of SAV in large, open water expanses presents a case of conflicting needs. On one hand, small scale, large area imagery containing ground control points would be useful for map registration purposes. On the other hand, low altitude, large scale, high resolution imagery might be necessary to compensate for adverse atmospheric conditions and provide sufficient information for detection of SAV. The abundance of SAV in such areas may be such that requirements for map registration could be eased without introducing significant error in coverage statistics. If this were the case, accurate position information (latitude, longitude, altitude, flight direction, aircraft attitude) might be sufficient to accurately estimate coverage in areas where there are insufficient ground control points for use in map registration.

MIPS is particularly well suited for delineation of features that have strong, distinct, multispectral (color, color-infrared) characteristics, such as tidal and non-tidal wetlands. Wetlands are typically small, linear features located along the shores of estuaries and small tributaries. Their small size requires the use of large scale, low altitude imagery to achieve adequate spatial resolution for detection. Results of the study demonstrate that MIPS has the capabilities for processing such high resolution imagery. In addition, wetlands have unique color characteristics that make them amenable for MIPS manual or automated feature delineation, based on multi-spectral properties.

Section 5

Recommendations

Based on the favorable results of the feasibility study, it is recommended that the MIPS evaluation be continued on site at W&M / VIMS, in order to assess its incorporation and performance in operational SAV distribution and abundance studies. Through constant use, procedural development, and periodic assessment, during an annual inventory, the strengths and weaknesses of MIPS, in an operational setting, will become apparent. Determination of workflow, processing steps, optimal workstation design, necessary modifications / extensions to MIPS routines, and interfaces with other GIS's would be components of the study.

The objective of continued operational evaluation of MIPS would be to develop a set of standard operating procedures (SOP's) for the use of MIPS in identification and extraction of natural resource coverage data (SAV, wetlands, shoreline features, etc.) from source imagery (photographic, video, or satellite). SOP's would cover source data requirements, system input methods, feature delineation routines, map transformation methods, quality control and assurance, incorporation of existing data sets (e.g. USGS DLG's), quantitative and qualitative feature attributes, data management, output data requirements, and interface with other GIS's.

A potentially valuable component of continued operational evaluation of MIPS would be detailed study of the incorporation of low altitude, video imagery in SAV and other natural resource inventories. If this medium can be used in a manageable, practical way, it offers potential for increasing the range of acceptable atmospheric conditions for conduction of aerial surveys, thereby widening flight "windows", facilitating data acquisition, and reducing collection costs. Video also has the advantage of being an economical, real-time, remote sensing, image medium that is amenable to near real-time data collection, analysis, and response to critical environmental situations.

Another valuable component of continued MIPS evaluation would be a thorough investigation of MIPS map registration and rectification routines as they relate to highly detailed natural resource feature mapping, such as tidal and non-tidal shorelines. Current instrumentation used for this purpose is manual, and while very accurate, the process is slow and labor intensive.

Results of an operational evaluation of MIPS would provide scientists and managers with decisive information regarding advantages / disadvantages of the incorporation of MIPS in extensive natural resource inventory, assessment, and management projects.

Section 6

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Table 1. Area measurements for 1987 SAV beds and geographic test areas computed by MIPS, VIMS SAV GIS, and pc ARC-INFO (units: square meters)

AREA LABEL		SAV Bed Area (square meters)		
MIPS	VIMS	MIPS	VIMS	pc ARC
Alexandria SAV Bed Areas				
MP07 -	AA	352439	306400	330786
MP06 -	BA	18959	24670	18479
SP04 -	BA	19823	24670	20203
MP05 -	CA	62061	61170	60458
SP03 -	CA	62898	61170	64277
MP03 -	DA	1589579	1779000	1548280
MP04 -	EA	82067	37650	79904
MP08 -	FA	37613	42970	36637
MP09 -	GA	10672	18100	10399
MP09 -	HA	2187	4778	2130
NP11 -	IA	3369	3285	3362
NP10 -	JA	5434	14430	5389
NP10 -	KA	2091	1864	2074
NP08 -	LA & MA	11115	9250	11027
NP06 -	QA	3717	7181	3679
NP05 -	RA	16653	19590	16455
NP01 &	MP01 - TA	1329565	1475000	1306591
NP03 -	UA	38573	43150	38233
NP04 -	VA	3653	5149	3612
MP02 &	NP02 - WA	812293	803900	791219
Mt. Vernon SAV Bed Areas				
SP05 -	AA	824387	820400	829859
SP01 -	MA	1968320	1933610	2101136
Alexandria Geographic Test Areas				
NPA1 -	00	148833	135913	147532
NPA3 -	00	294838	298145	292007
NPA2 -	00	621254	592906	615638
MPA1 -	00	146806	135913	142945
MPA2 -	00	596958	569208	581484
MPA4 -	00	348727	330801	339746
MPA3 -	00	257644	231622	250972
SPA2 -	00	533092	569208	544522
SPA4 -	00	335776	330801	343040
SPA3 -	00	233089	231622	238072

Table 1. (continued)

AREA LABEL		SAV Bed Area (square meters)		
MIPS	VIMS	MIPS	VIMS	pc ARC
Mt. Vernon Geographic Test Area				
SPA1 -	00	603473	579708	616637
Bloodsworth SAV Bed Areas				
0503-7 -	AA	6124	8513	6106
0503-6 -	BA	11308	15190	11261
0602-4 -	CA	31672	23440	32070
0602-5 -	DA	6699	20300	6759
0501-5 -	DB	116822	159100	114524
0602-6 -	EA	3530	12220	3580
0501-6 -	EB	16427	24730	16083
0602-1 -	FA	297797	358200	301741
0503-1 -	FB	48963	53660	48487
0503-5 -	GB	17222	26310	17074
0602-3 -	HA & GA	132770	126813	134612
0503-4 -	HB	116785	165500	115581
0602-2 -	IA	75272	35130	76238
0503-3 -	IB	33134	73810	32719
0603-6 -	JA	2381007	2492000	2247513
0603-8 -	JB	10248	36950	9986
0503-2 -	JB	11161	36950	11045
0603-7 -	KA	101132	64730	98376
0603-2 -	KB	207206	201600	201386
0603-5 -	LA	57915	69290	56316
0603-1 -	LB	4760	5107	4635
0603-4 -	MA	5133	10740	4964
0603-3 -	OA	28689	12820	27848
0605-8 -	PA	203186	270200	197609
0605-7 -	QA	173561	185000	168758
0605-6 -	RA	6803	15720	6640
0605-5 -	SA	269192	311000	261745
0501-4 -	SA	385227	311000	377687
0605-4 -	TA	58374	67890	56771
0501-3 -	TA	62909	67890	61694
0605-2 -	VA	41815	54490	40577
0501-2 -	VA	40174	54490	39411
0605-1 -	WA	2087	2428	2000
0501-1 -	WA	2820	2428	2767

Table 1. (continued)

AREA LABEL		SAV Bed Area (square meters)		
MIPS	VIMS	MIPS	VIMS	pc ARC
Bloodsworth Geographic Test Areas				
0605-A1	00	385666	383890	374634
0605-A2	00	1720824	1676505	1673152
0603-A1	00	69429	67514	67629

Table 2. Results of statistical comparisons of geographic test areas and SAV bed areas measured by MIPS, VIMS SAV GIS, and pc ARC-INFO. (units: square meters)

Abbreviations used:
ADF1 - absolute diff. VIMS & MIPS
RDF1 - relative diff. VIMS & MIPS
ADF2 - absolute diff. VIMS & pc ARC
RDF2 - relative diff. VIMS & pc ARC
ADF3 - absolute diff. MIPS & pc ARC
RDF3 - relative diff. MIPS & pc ARC
MEAN - Mean or average value
SD - standard deviation
N - number of samples

Geographic Test Areas

MEANMIPS	MEANVIMS	MEANARC
449744	438125	444860

MEANADF1	MEANRDF1	MEANADF2	MEANRDF2	MEANADF3	MEANRDF3
17250	.05	12935	.04	10151	.02

SDMIPS	SDVIMS	SDARC
407563	398345	396901

SDADF1	SDRDF1	SDADF2	SDRDF2	SDADF3	SDRDF3
14060	.03	9851	.03	11629	.01

NMIPS	NVIMS	NARC
14	14	14

Sav Bed Areas

MEANMIPS	MEANVIMS	MEANARC
218311	229875	214085

MEANADF1	MEANRDF1	MEANADF2	MEANRDF2	MEANADF3	MEANRDF3
23320	.30	27648	.31	6272	.02

SDMIPS	SDVIMS	SDARC
489093	510551	477992

SDADF1	SDRDF1	SDADF2	SDRDF2	SDADF3	SDRDF3
36125	.29	49576	.29	19485	.01

NMIPS	NVIMS	NARC
56	56	56

Table 3. Results of statistical analysis of correlation between geographic test areas and SAV bed areas measured by VIMS SAV GIS and MIPS

Abbreviations used: N - number of samples
SIG - significance level

SAV Potomac Test Area Correlations

VIMS	.9946
with	N(11)
MIPS	SIG .000

SAV Potomac Bed Correlations

VIMS	.9971
with	N(22)
MIPS	SIG .000

SAV Bloodsworth Test Area Correlations

VIMS	1.0000
with	N(3)
MIPS	SIG .001

SAV Bloodsworth Bed Correlations

VIMS	.9979
with	N(34)
MIPS	SIG .000

SAV Potomac & Bloodsworth Test Area Correlations

VIMS	.9991
with	N(14)
MIPS	SIG .000

SAV Potomac & Bloodsworth Bed Correlations

VIMS	.9975
with	N(56)
MIPS	SIG .000

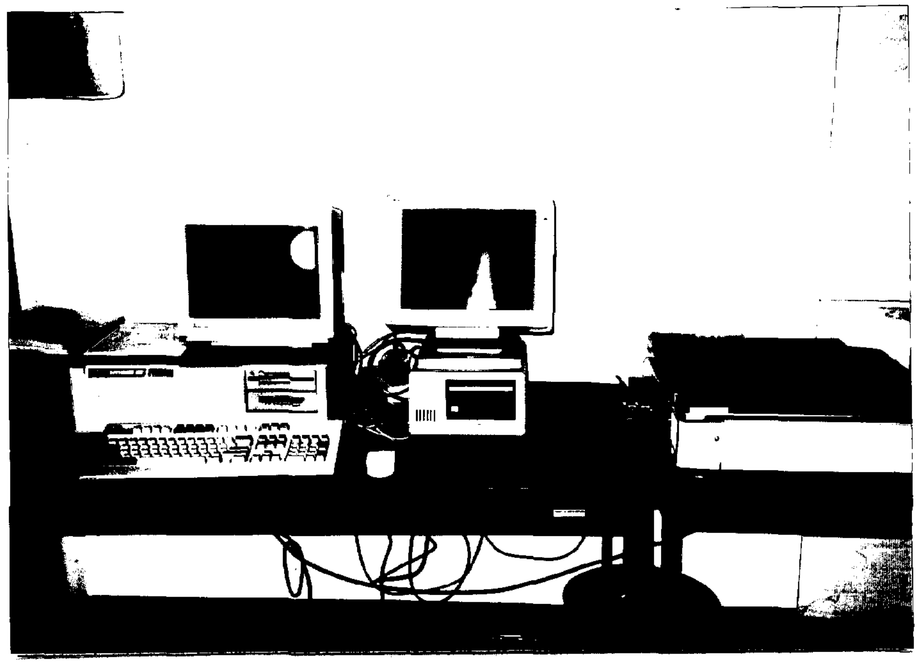


Figure 1. MIPS workstation at Salisbury St. Univ., with (l-r) "386" pc-AT with monitor, mouse, 512 H by 480 V medium-res color monitor, WORM optical disk drive, and 300 dpi color scanner.

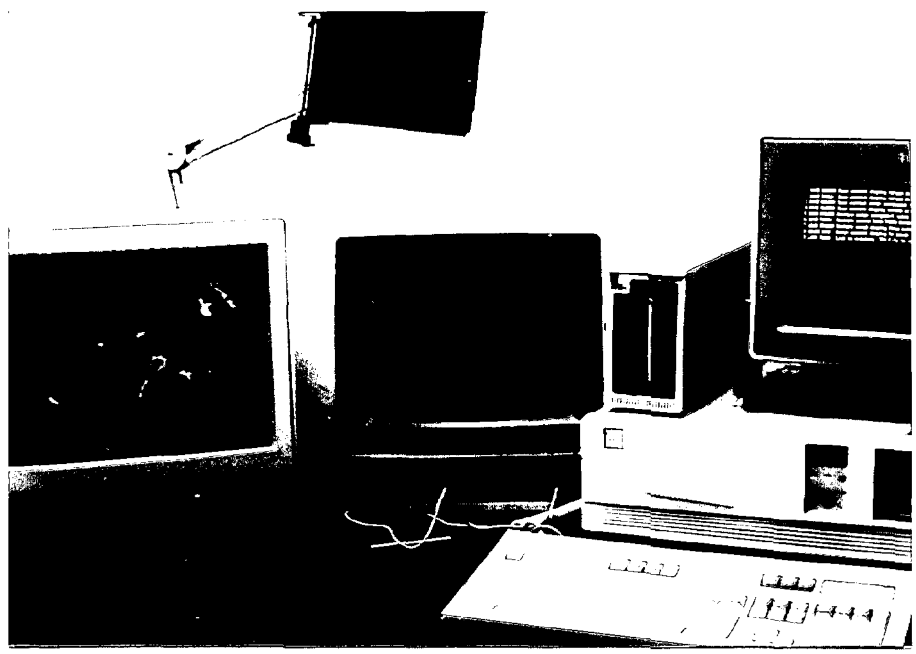


Figure 2. MIPS Workstation at Va. Council on the Environment, with (l-r) 1280 H by 1024 V high-res color monitor, 512 H by 480 V medium-res color monitor, 800 Mbyte optical disk drive, "386" pc-AT with monitor.

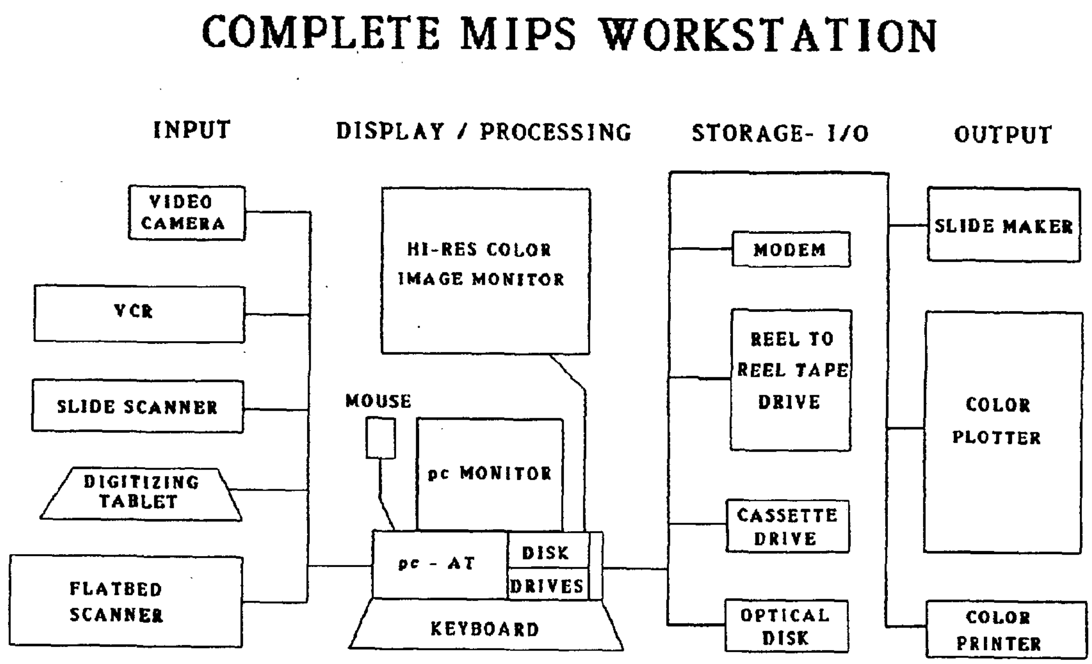


Figure 3. Schematic of complete MIPS workstation.

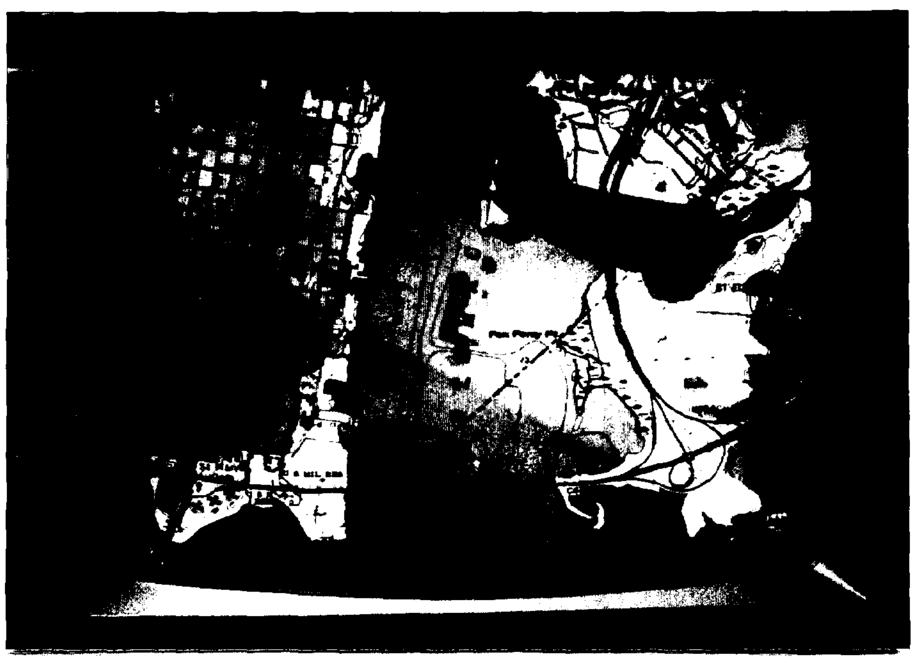


Figure 4. Portion of USGS Alexandria, VA - DC - MD, 1965 (Photorevised 1971 and Photoinspected 1972), 7.5 minute quad map scanned into MIPS at 200 dpi and displayed on a high-res color monitor.

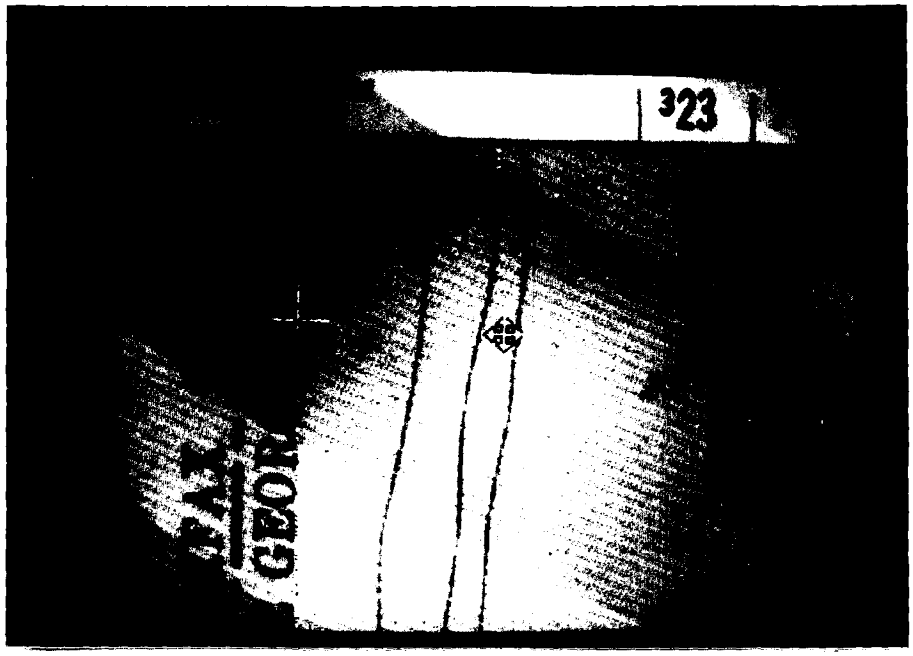


Figure 5. Fiducial mark for N 38 deg. 45 min., W 77 deg. 2.5 min. on a scanned portion of the USGS Mount Vernon, VA - MD, 1966 (Photorevised 1971), 7.5 minute quad map selected as a ground control point for MIPS quad map registration.

Figure 6. First step of color scanner input - scanning entire color positive, 9" by 9", 2 September 1987 aerial photo contact print of the Alexandria, VA area in low-res mode for positioning.

Figure 7. Color positive, 9" by 9", 2 September 1987 aerial photo contact print of the Alexandria, VA area scanned into MIPS at approximately 75 dpi and displayed on the hi-res color monitor.

Figure 8. Black and white, 9" by 9", 25 September 1987 positive aerial photo contact print of the Alexandria, VA area, scanned by MIPS at approximately 100 dpi and displayed on the hi-res color monitor.

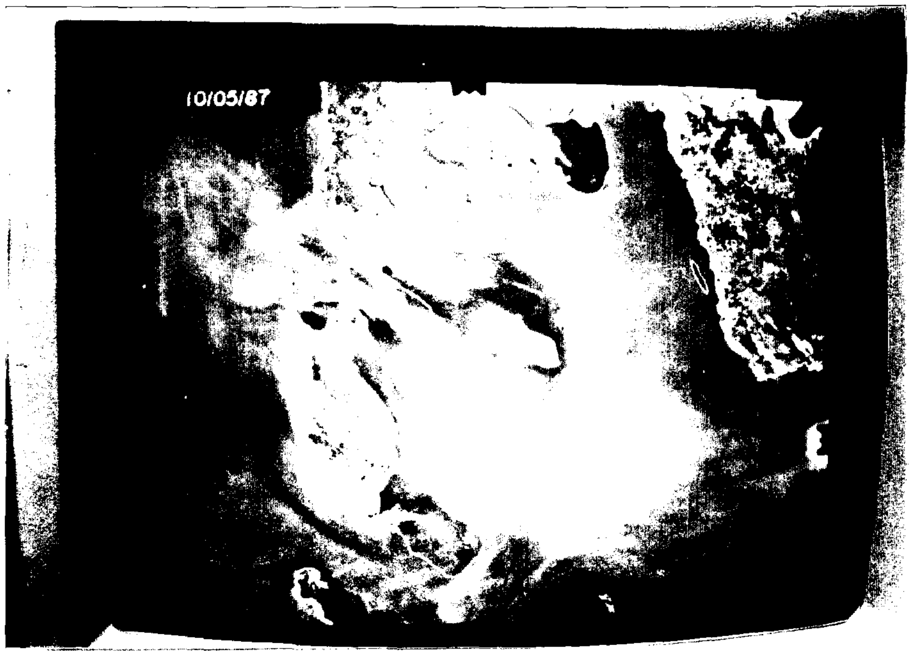


Figure 9. Black and white, 9" by 9", 5 October 1987, positive aerial photo contact print of the Bloodsworth Is., MD area, scanned by MIPS at approximately 100 dpi and displayed on the hi-res color monitor (SAV areas outlined in yellow using mouse).

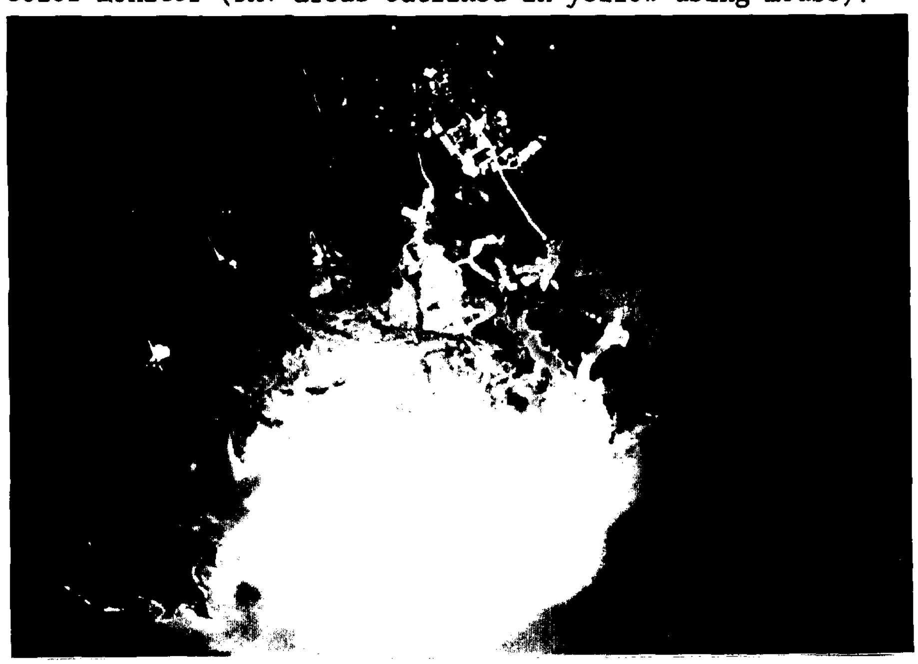


Figure 10. Color positive, 9" by 9", 28 June 1987 aerial photo color film contact transparency of the lower York River area scanned into MIPS at approximately 100 dpi and displayed on the hi-res color monitor.

Figure 11. Color hardcopy print of a captured aerial video image of the Gloucester Pt., VA area, taken at 670 meters (2200 feet) on 26 October 1988. An SAV bed is visible extending from lower right to just below the pier.

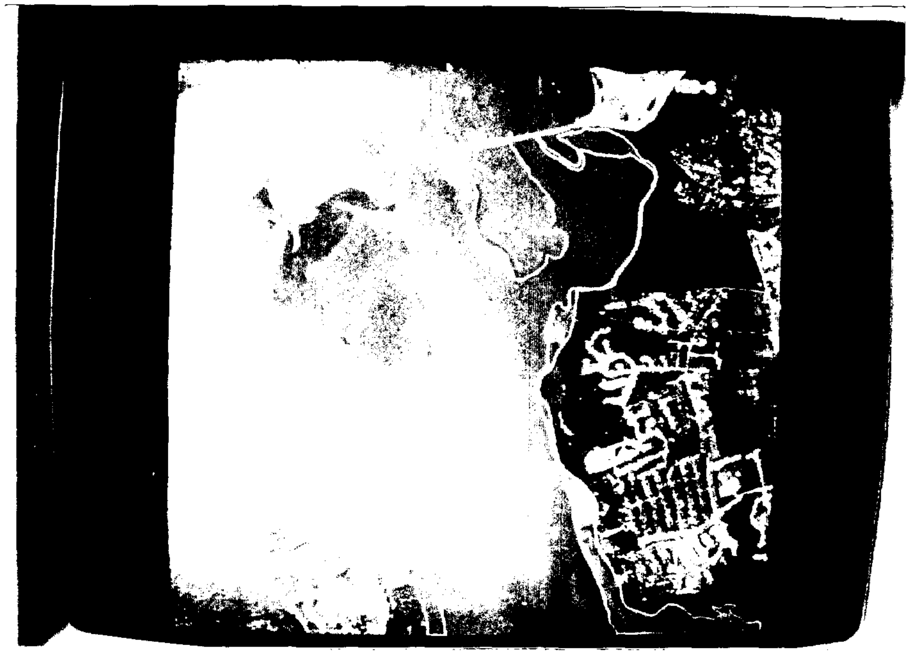


Figure 12. SAV beds in the Alexandria, VA, Mount Vernon, VA area, manually delineated in yellow, using a mouse.

Figure 13. "Zoomed" view of SAV areas in the Bloodsworth Island, MD area, manually delineated using a mouse. The yellow outline is completed. The white is still under construction.

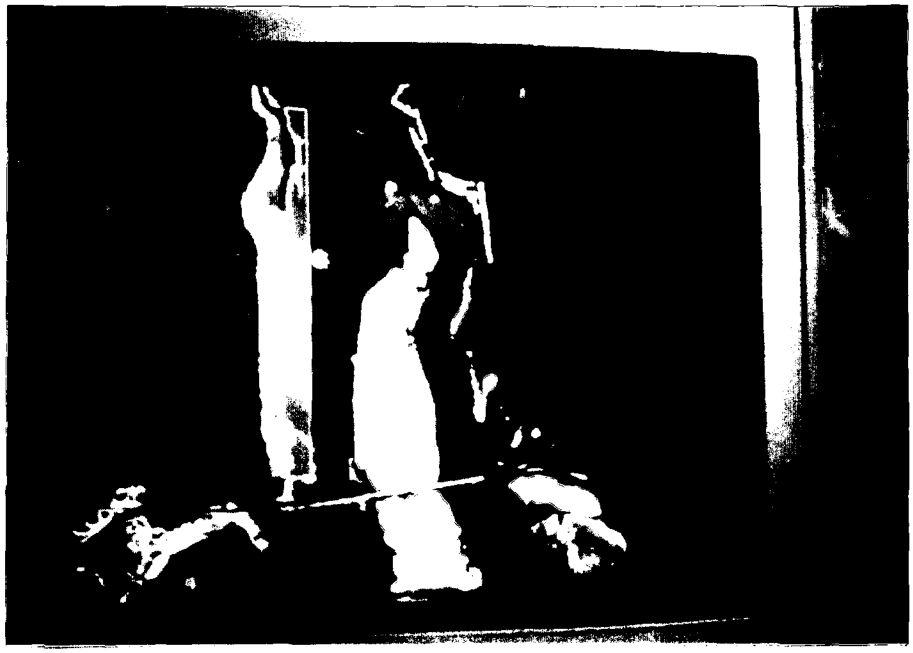


Figure 14. SAV areas (yellow) in the Alexandria, Va area, delineated by MIPS feature mapping routine. Blanked areas, not included in the analysis, appear dark on the image.

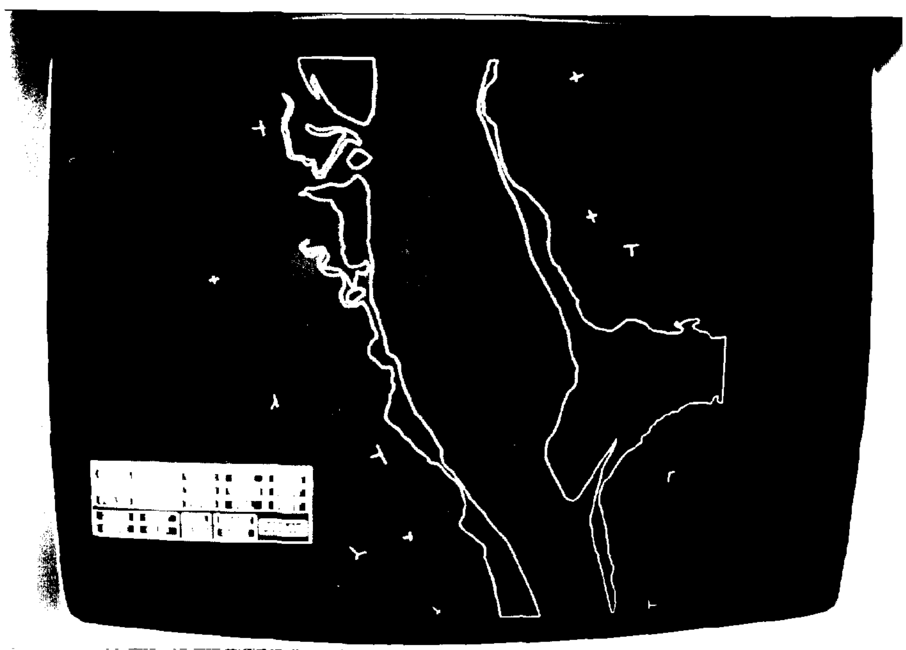


Figure 15. SAV vector outlines in the Alexandria, VA, Mount Vernon, VA area, created by MIPS "Auto-Line" function.

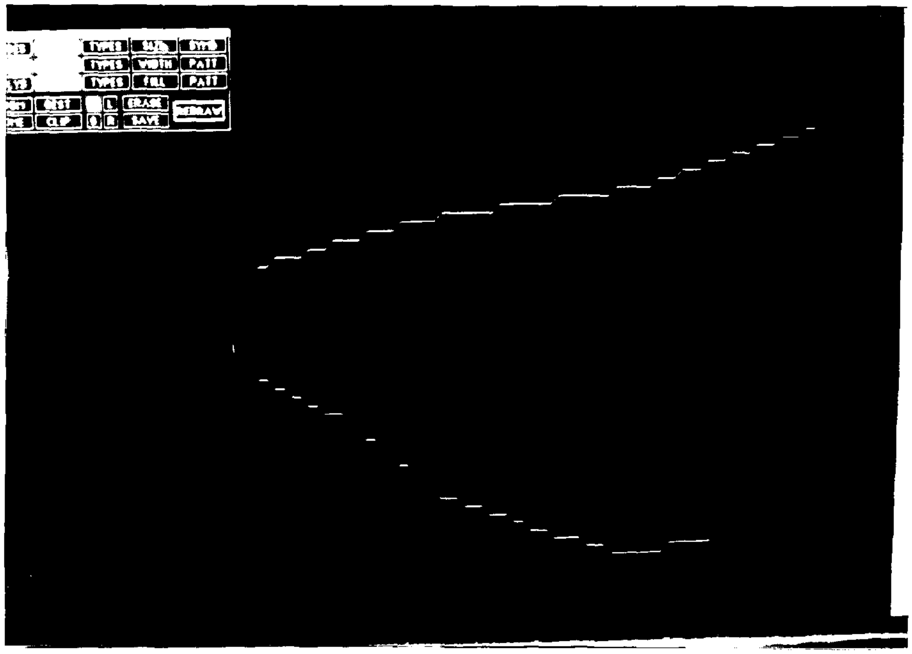


Figure 16. "Zoomed" view of an SAV vector outline in the Bloodsworth Island, Md area, displaying typical jagged effect, resulting from the direct raster to vector transformation, with no thinning or smoothing applied.

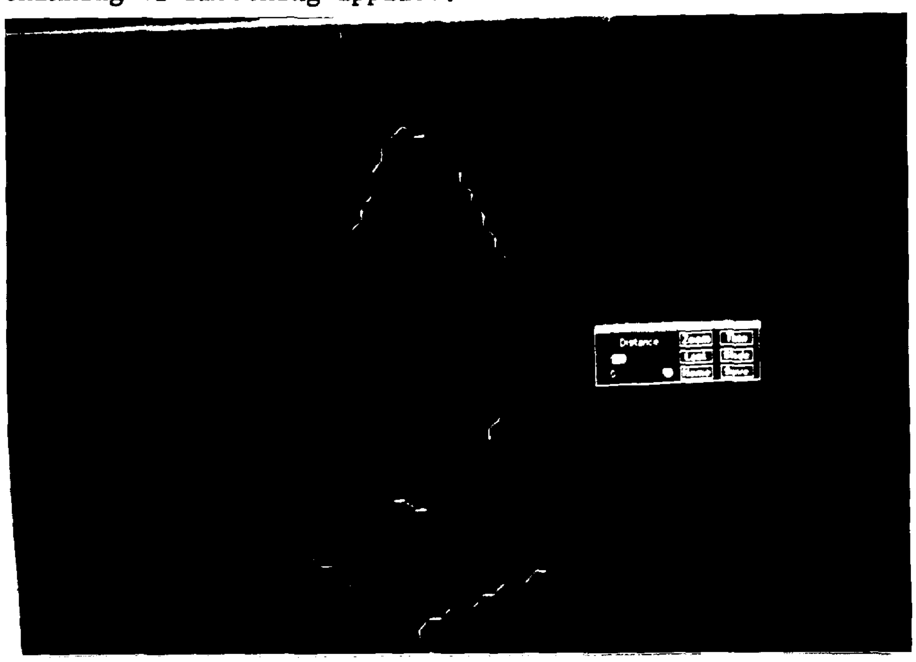


Figure 17. "Zoomed" view of an SAV outline in the Bloodsworth Island, MD area, before (white) and after (green) applying MIPS "Thin-Vect" function to thin and smooth jagged artifacts created in raster to vector transformation.

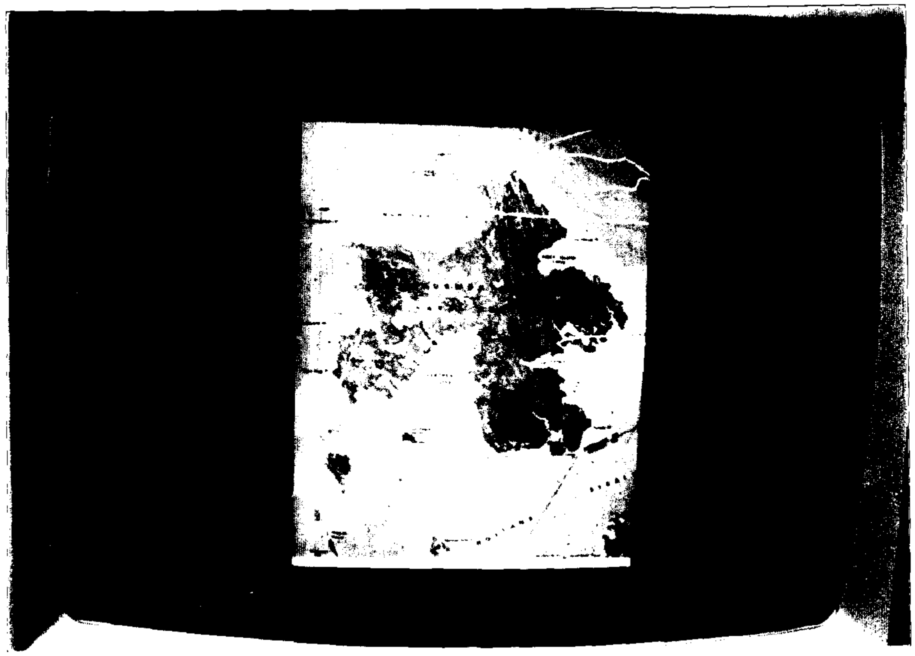


Figure 18. SAV vector outlines in the Bloodsworth Island, MD area displayed in white over portion of a scanned USGS Bloodsworth Island, MD, 1973, 7.5 minute quad map of the area.

Figure 19. "Zoomed" view of vector ground control point "3" (white cross) in the process of being "dragged", via mouse, to the corresponding feature on the scanned USGS Bloodsworth Island, MD, 1973, 7.5 minute quad map.

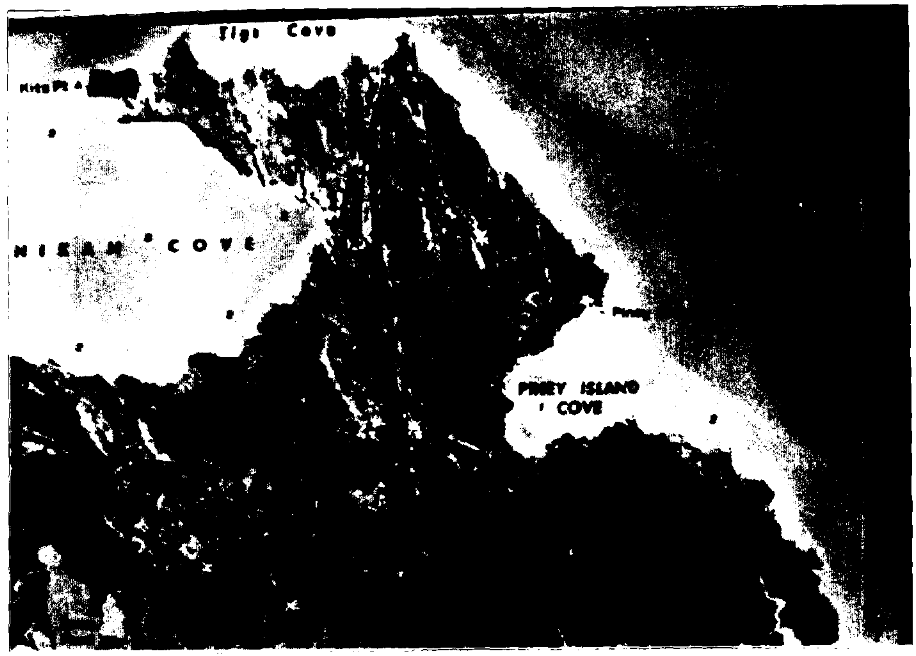


Figure 20. Linear least-squares map transformation of SAV vector outlines (white) in the Bloodsworth Island, MD area overlayed on a scanned portion of the USGS Bloodsworth Island, MD, 1973, 7.5 minute quad map. Note close correspondence of ground control points.

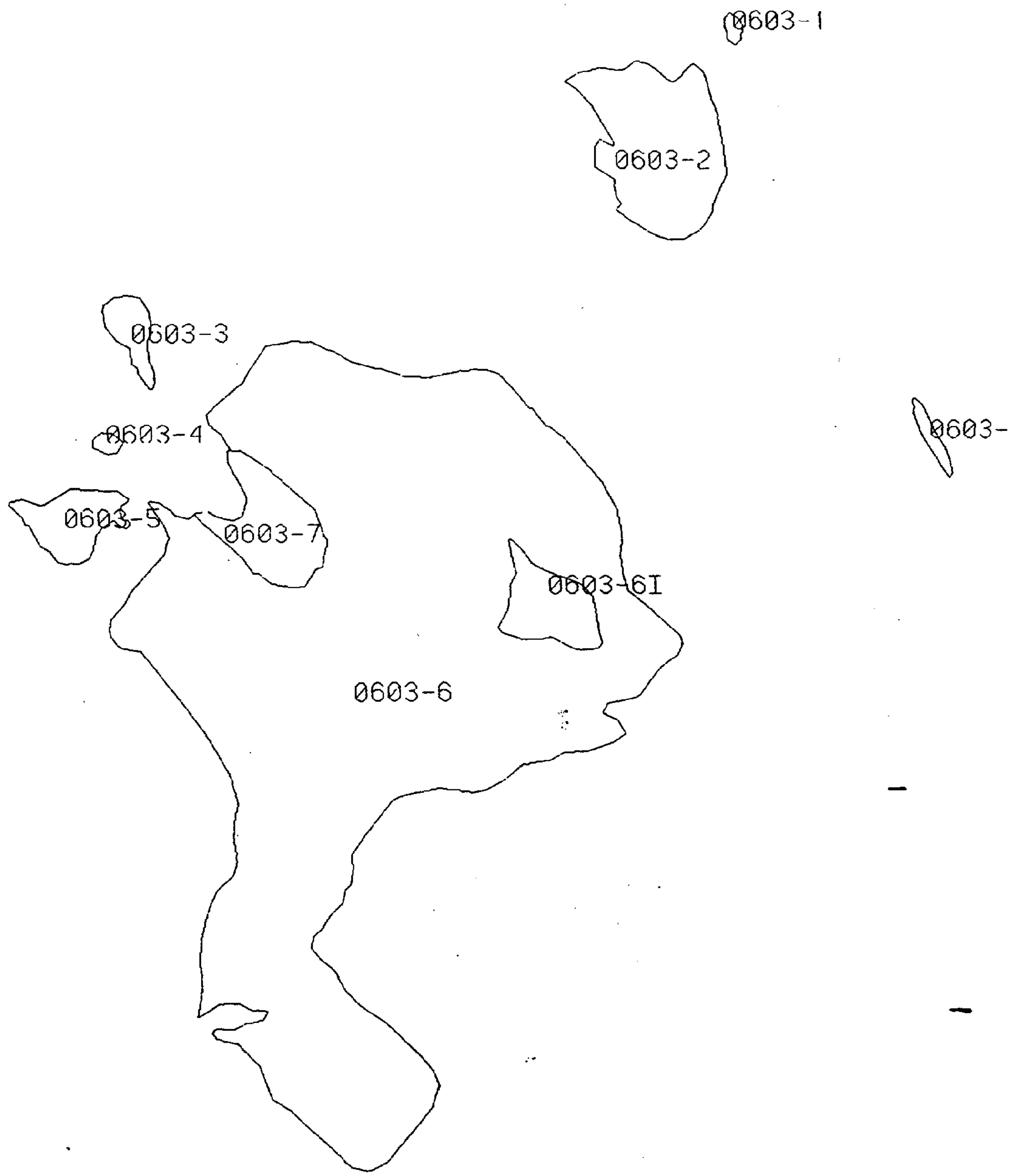


Figure 21. SAV polygons in the Bloodsworth Island, MD area, created by MIPS, imported and plotted by pc ARC-INFO.

Figure 22. USGS Alexandria, VA - DC - MD, 1965 (Photorevised 1979), 7.5 minute (topographic), 1:24,000, mylar base quad map edition with SAV beds and geographic test areas labeled and outlined in bold ink (after Orth et. al, 1989).

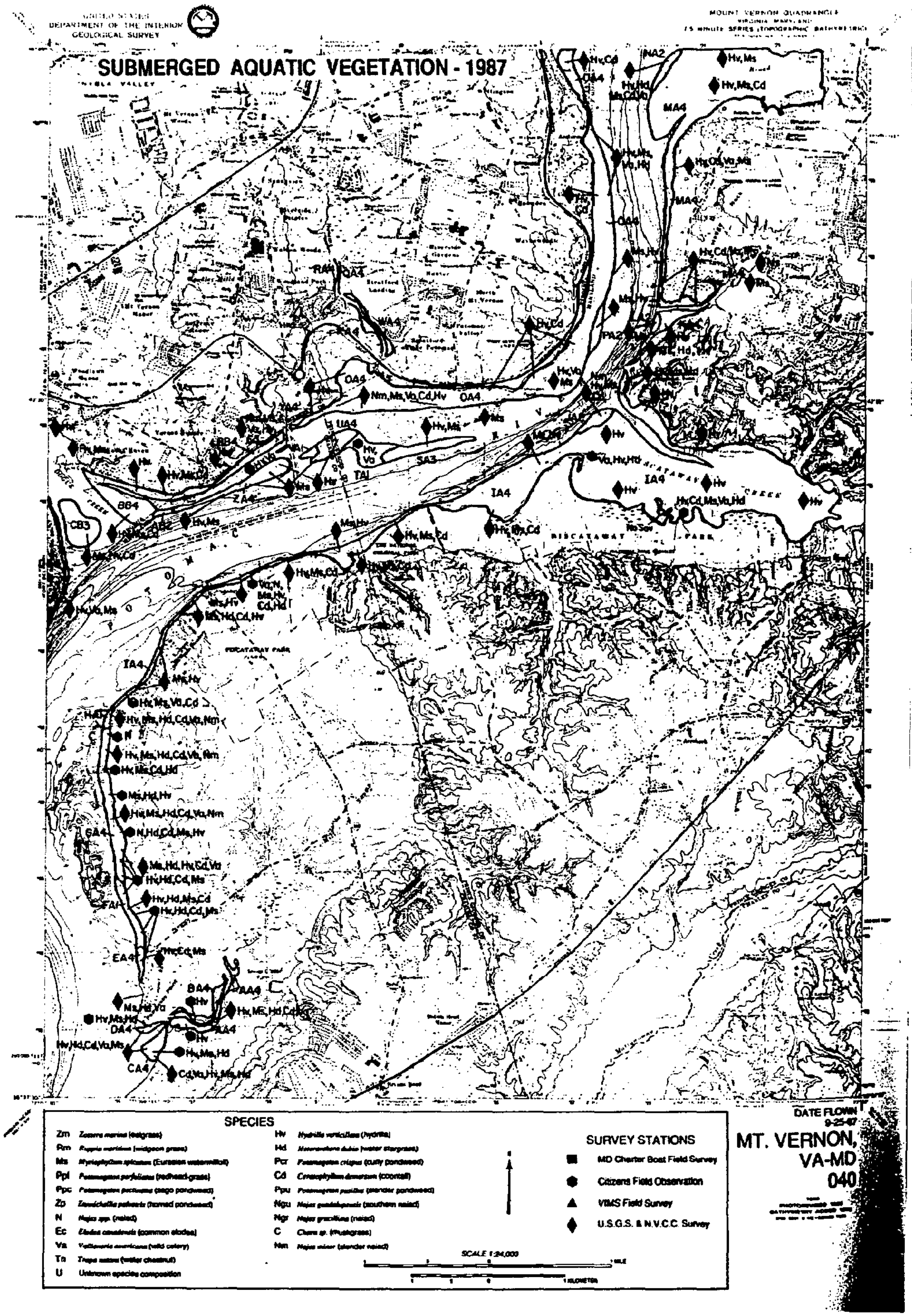


Figure 23. USGS Mount Vernon, VA - MD, 1966 (Photorevised 1983, Bathymetry Added 1982), 7.5 minute (topographic-bathymetric), 1:24,000, mylar base, quad map edition with SAV beds and geographic test areas labeled and outlined in bold ink (after Orth et. al, 1989).

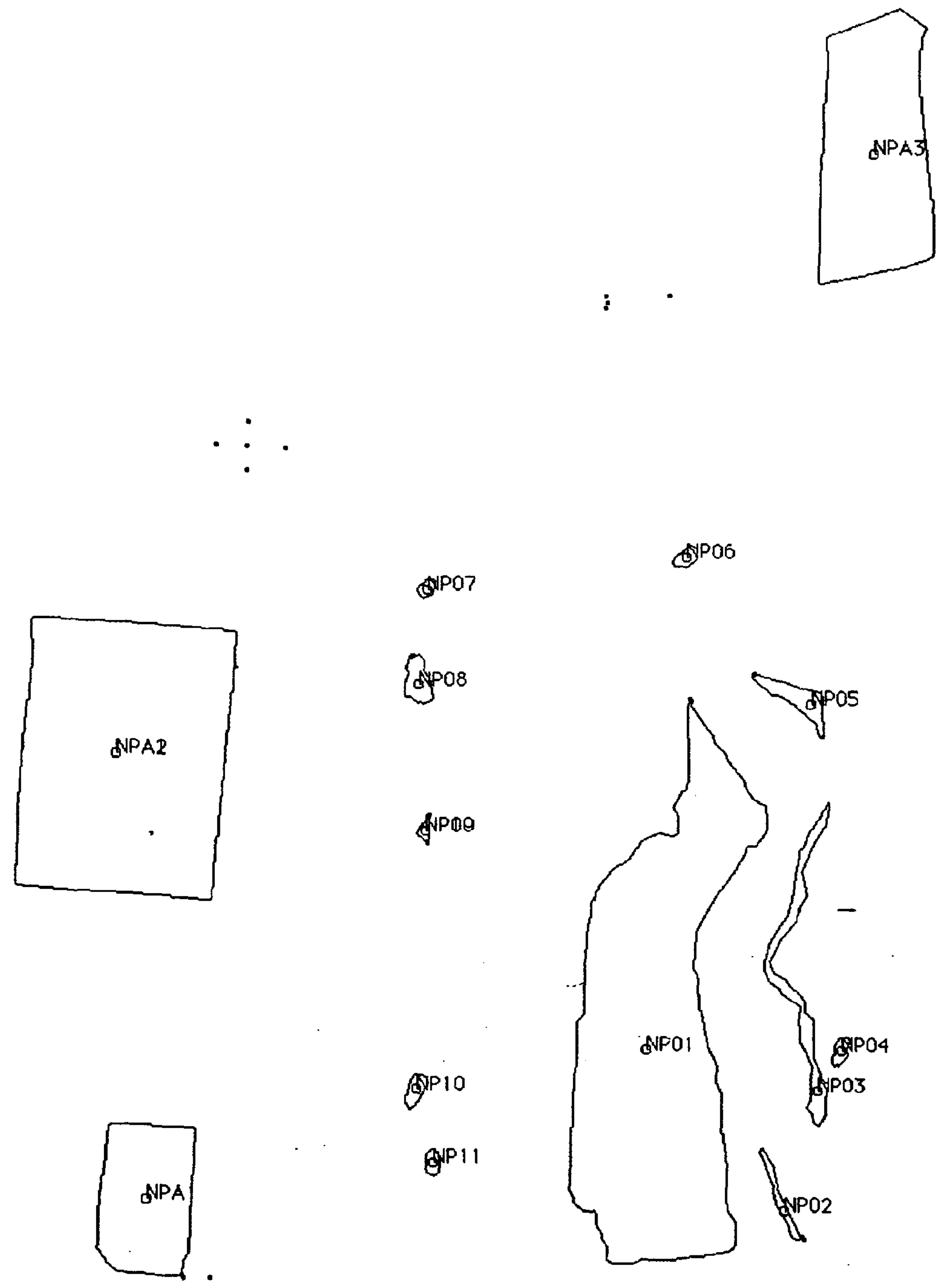


Figure 25. MIPS derived SAV and geographic test area polygon outlines plus ground control points from aerial photograph 129-4, 2 September 1987 (northern Alexandria, VA area).

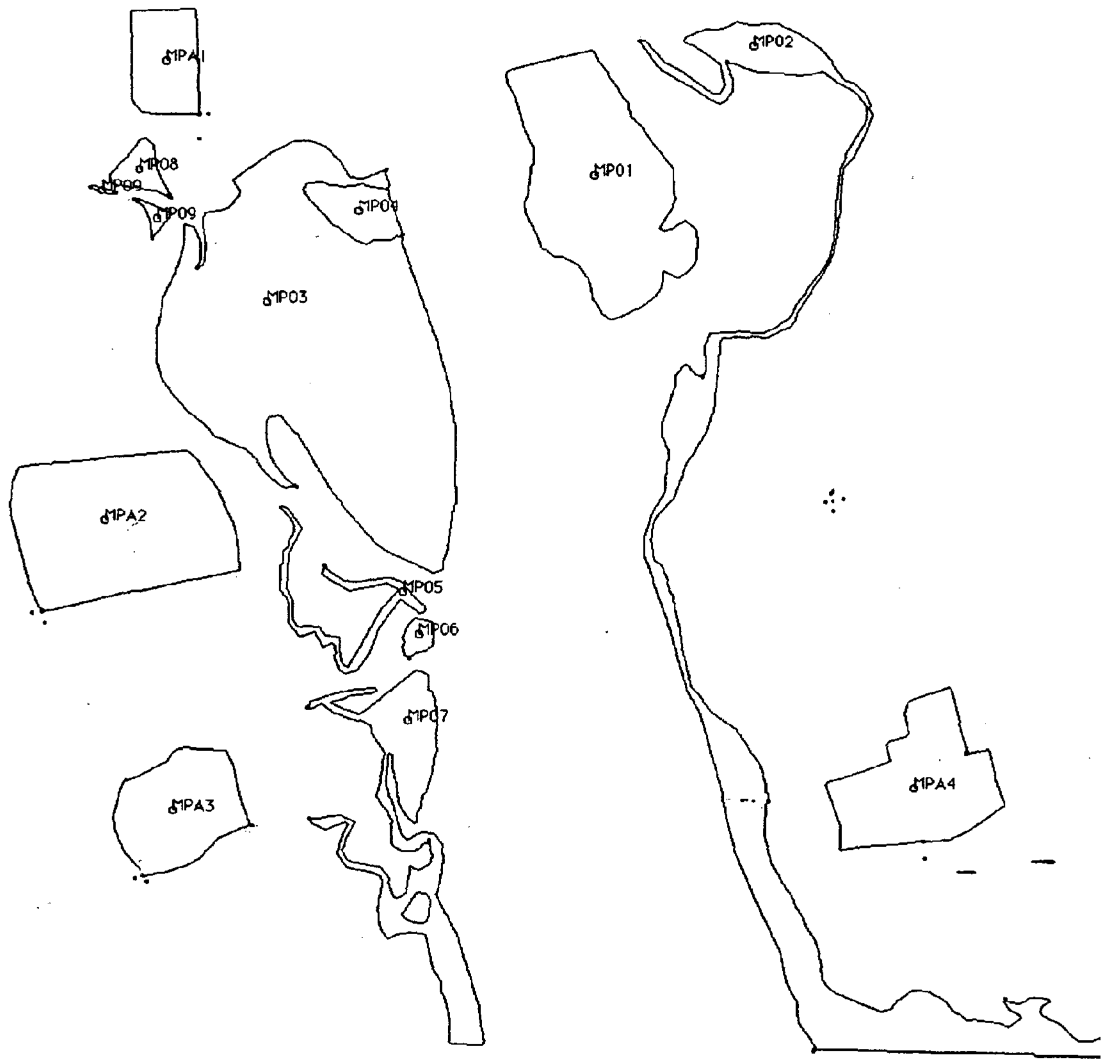


Figure 26. MIPS derived SAV and geographic test area polygon outlines plus ground control points from aerial photograph 129-6, 2 September 1987 (central Alexandria, VA area).

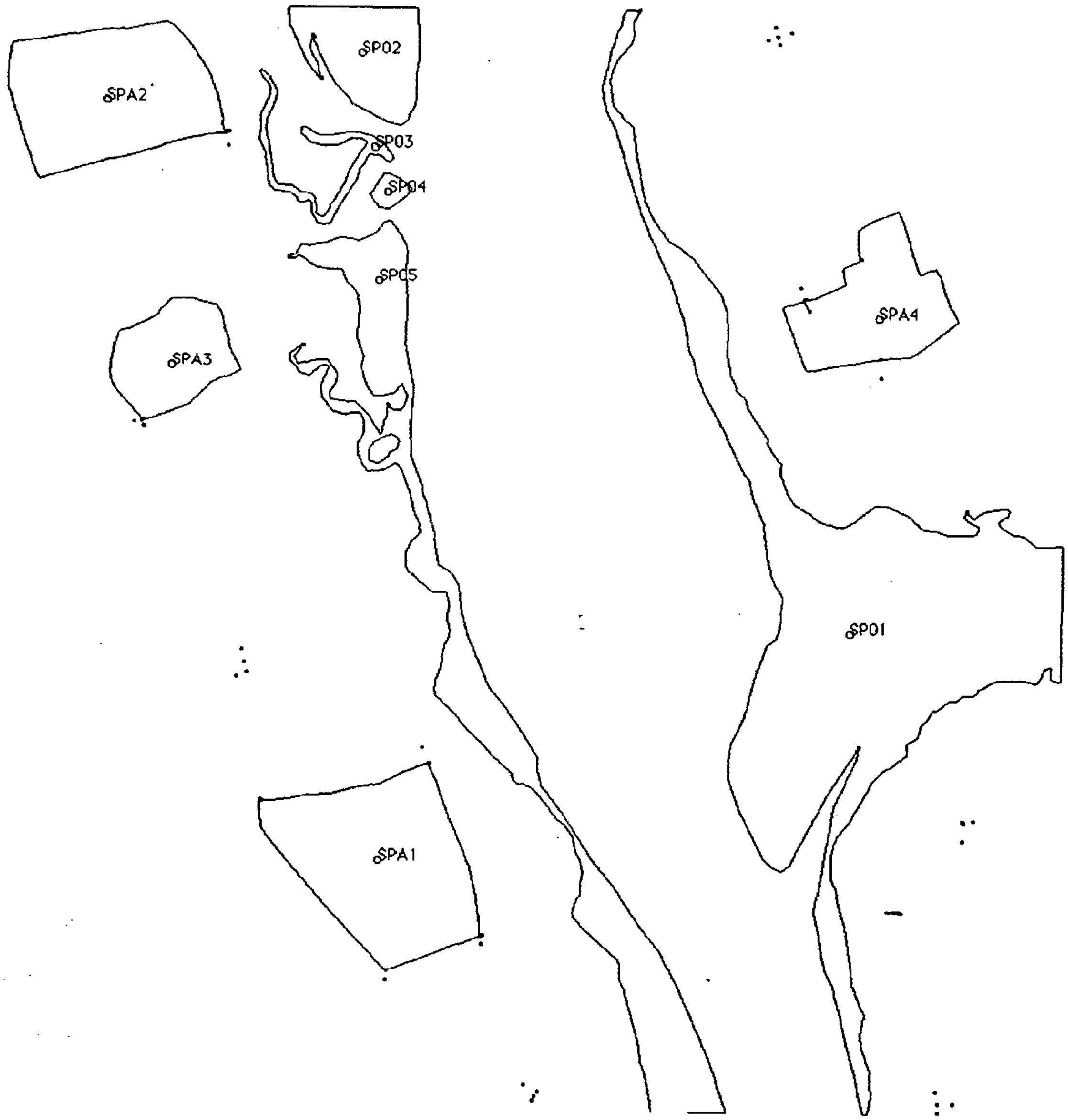


Figure 27. MIPS derived SAV and geographic test area polygon outlines plus ground control points from aerial photograph 129-7, 2 September 1987 (southern Alexandria, VA - northern Mt. Vernon, VA area).

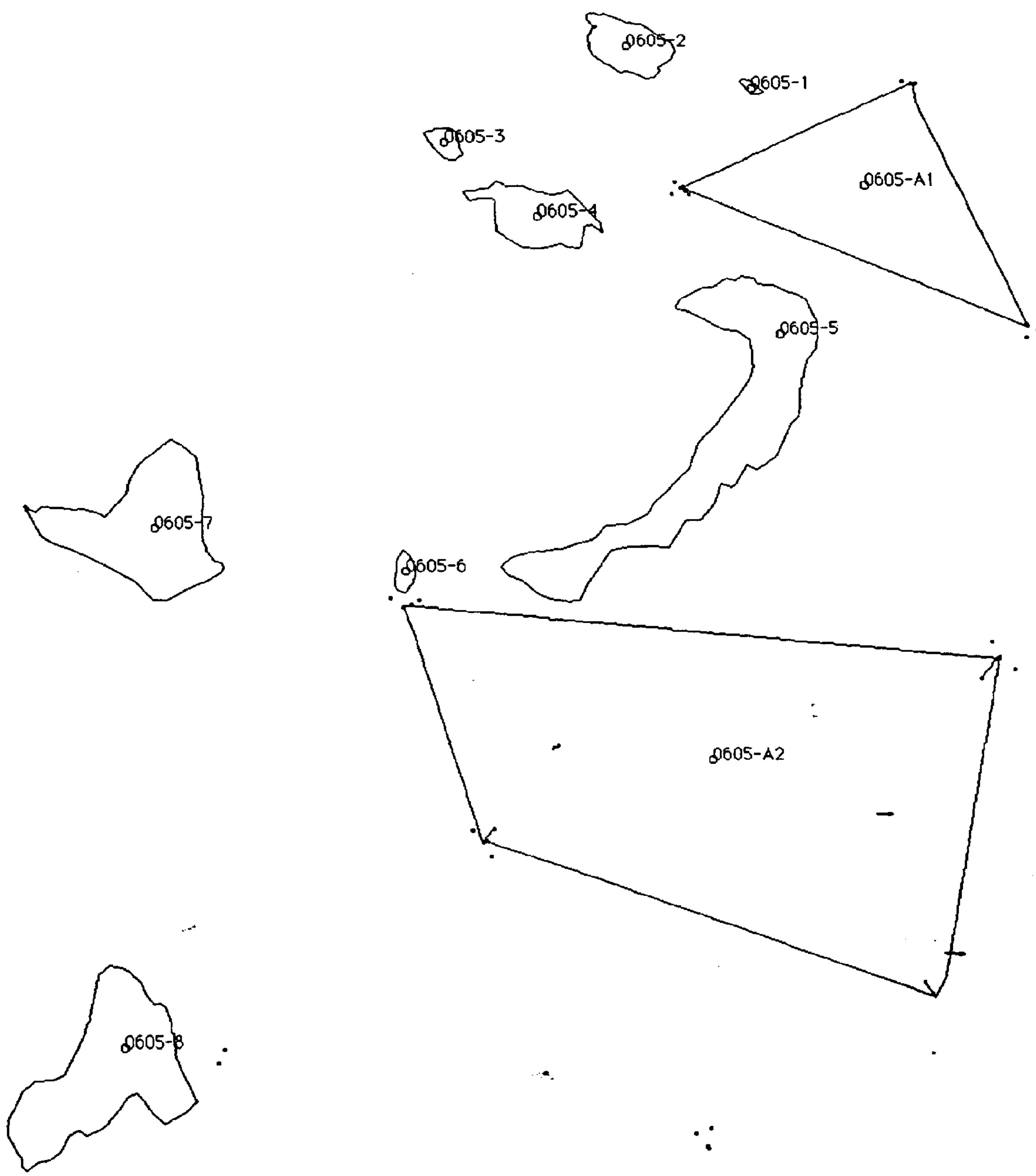


Figure 28. MIPS derived SAV and geographic test area polygon outlines plus ground control points from aerial photograph 06-05, 5 October 1987 (northwest section of Bloodsworth Island, MD).

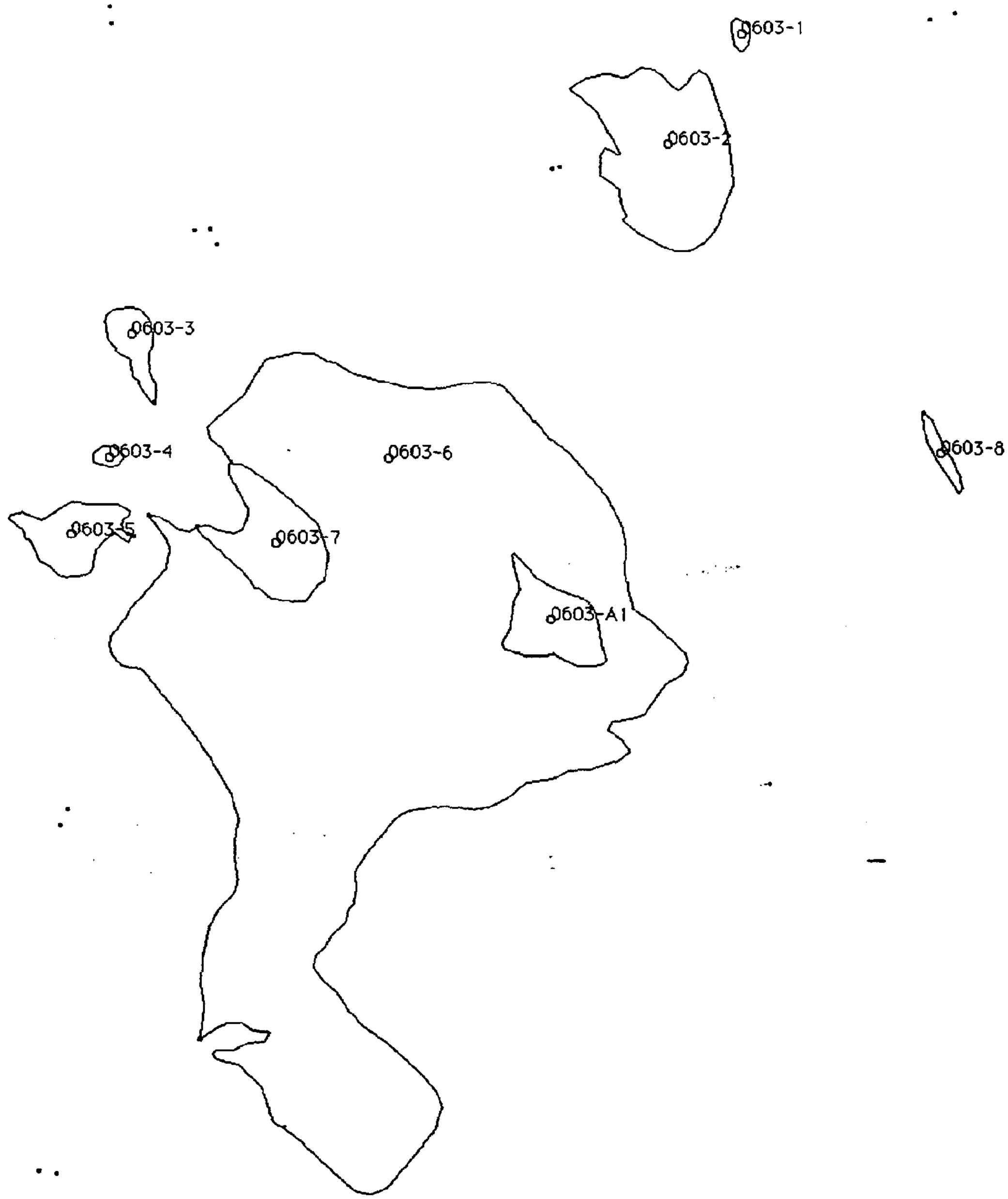


Figure 29. MIPS derived SAV and geographic test area polygon outlines plus ground control points from aerial photograph 06-03, 5 October 1987 (west central section of Bloodsworth Island, MD).

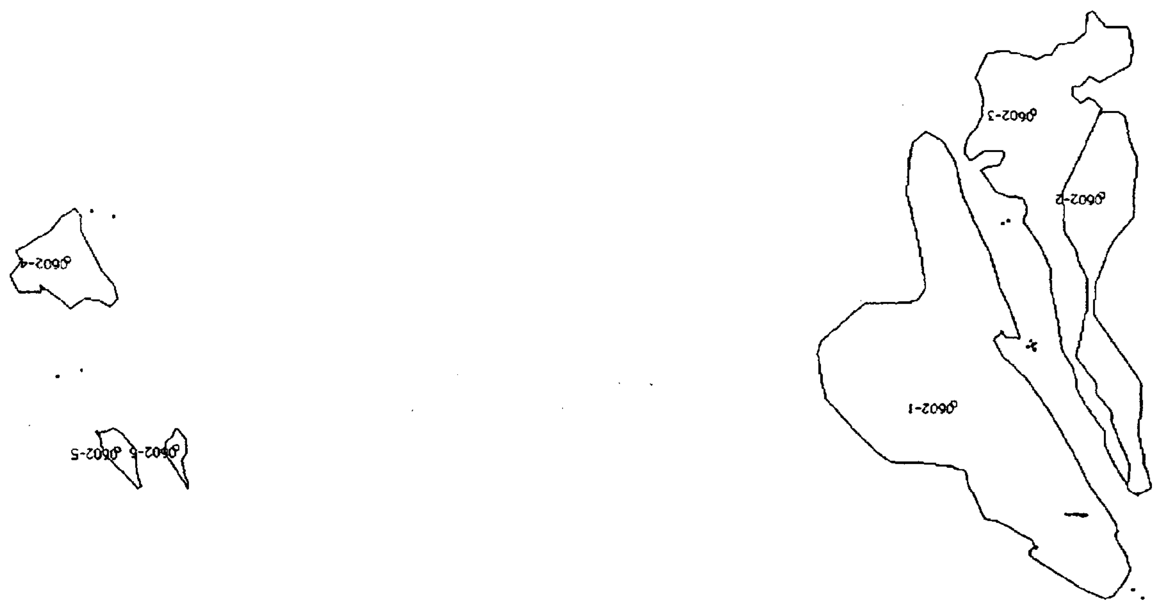


Figure 30. MIPS derived SAV and geographic test area polygon outlines plus ground control points from aerial photograph 06-02, 5 October 1987 (southwest section of Bloodsworth Island, MD).

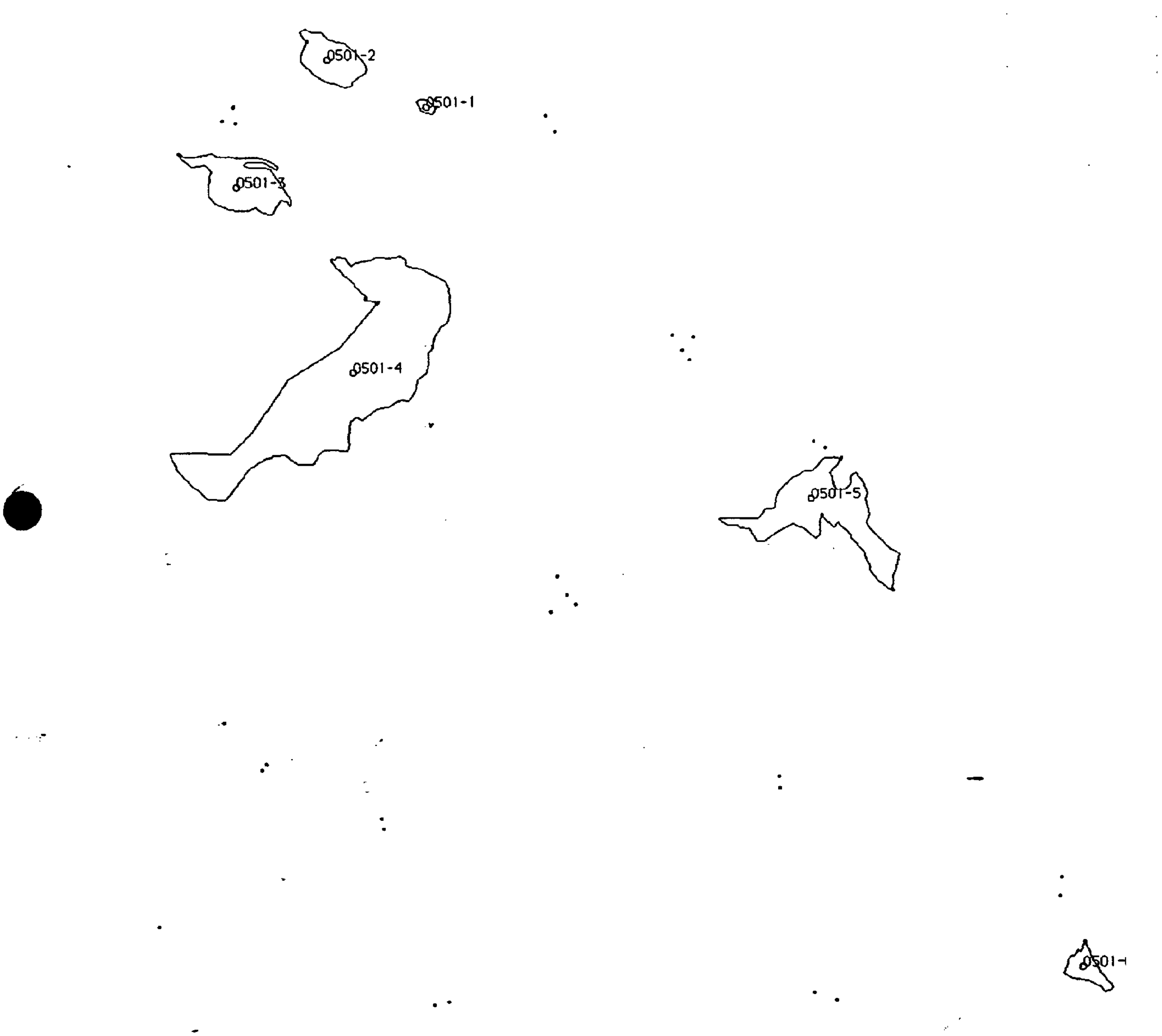


Figure 31. MIPS derived SAV and geographic test area polygon outlines plus ground control points from aerial photograph 05-01, 5 October 1987 (northeast section of Bloodsworth Island, MD).

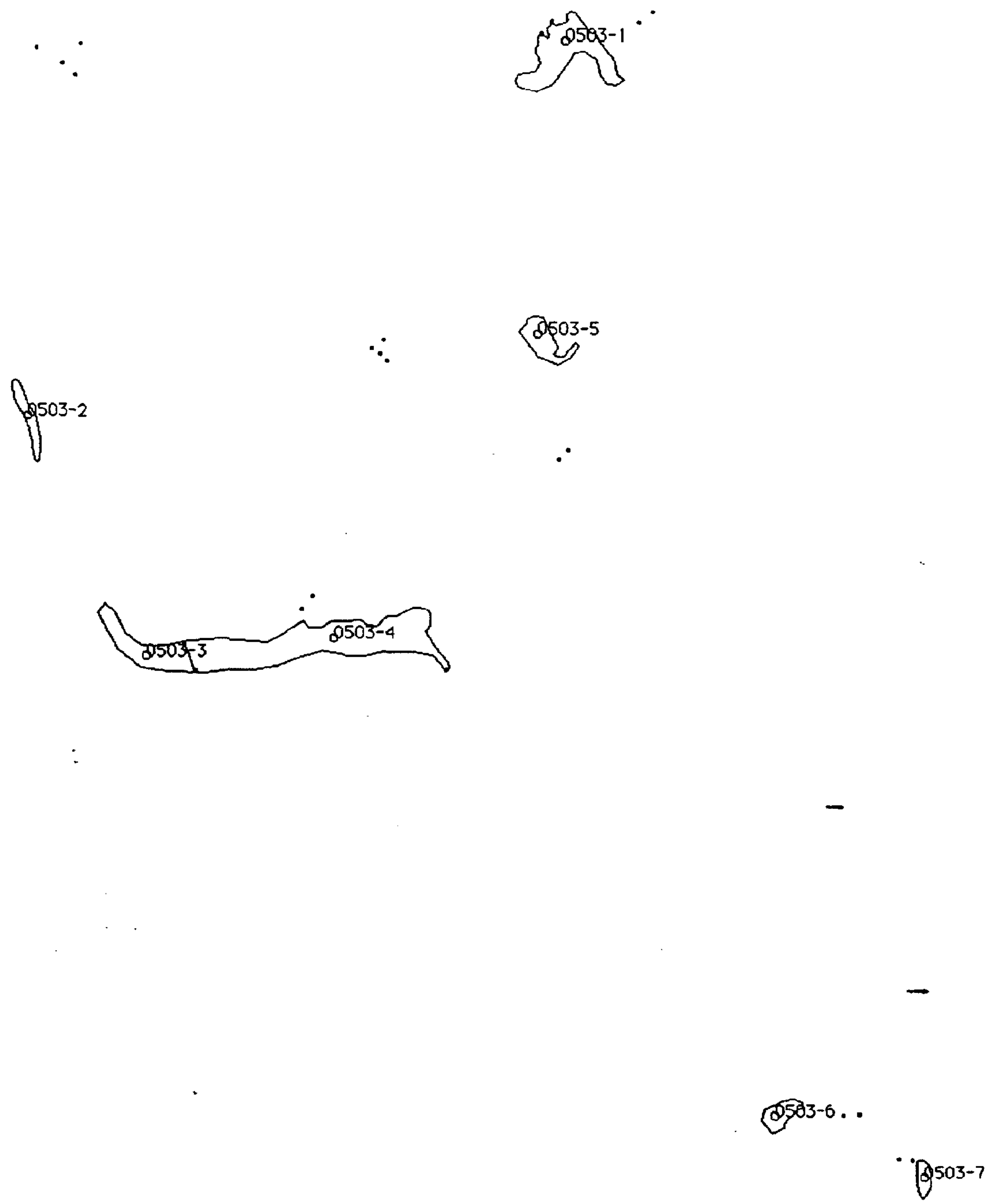
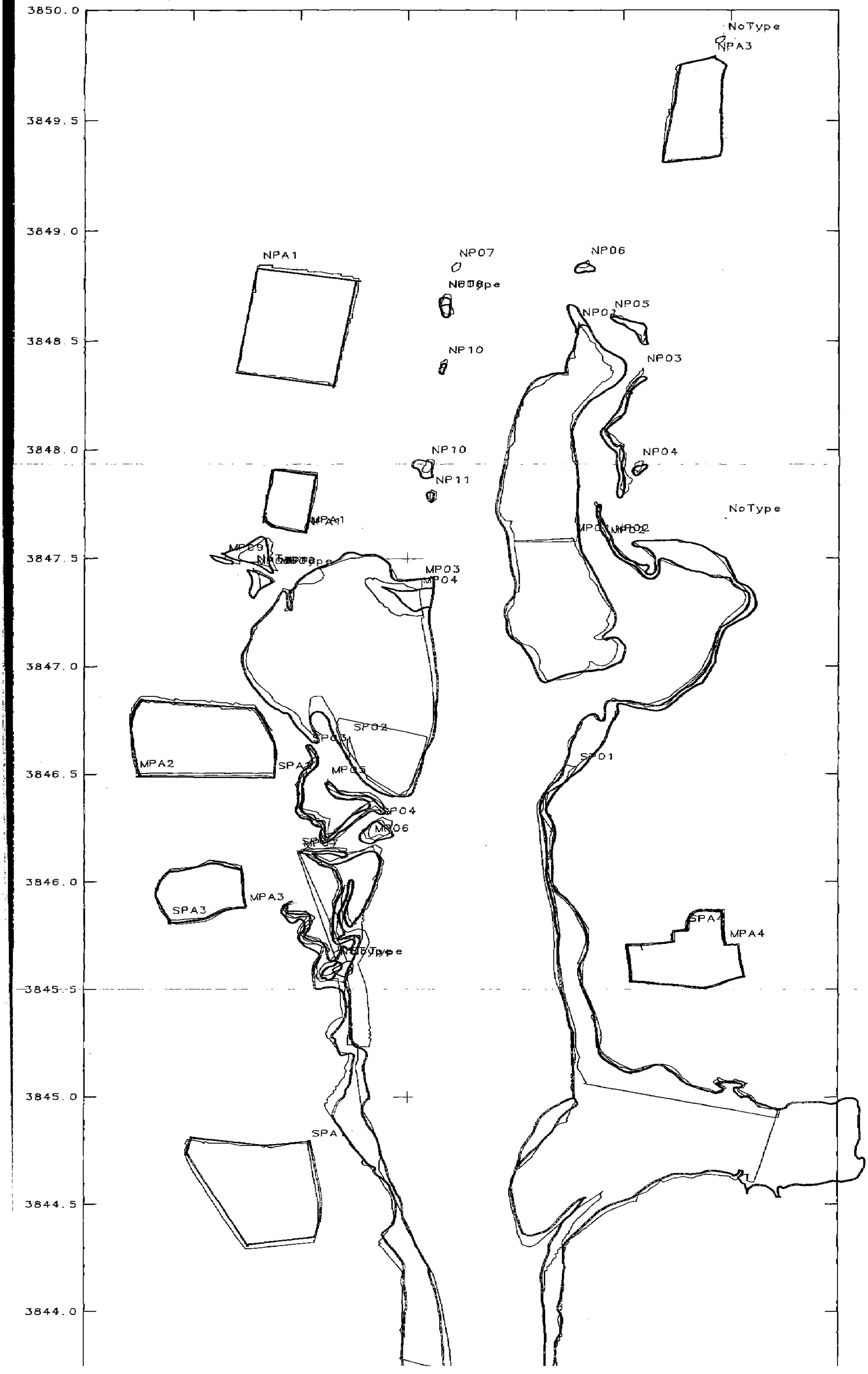


Figure 32. MIPS derived SAV and geographic test area polygon outlines plus ground control points from aerial photograph 05-03, 5 October 1987 (southeast section of Bloodsworth Island, MD).

Figure 33. MIPS SAV polygons (red) and VIMS photo-interpreted outlines of SAV beds (green) in the Alexandria, VA, Mount Vernon, VA area, overlayed on NOS shoreline (1:24,000) (figure included in plastic page insert).

Fig 33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NP10
NP04
NP11
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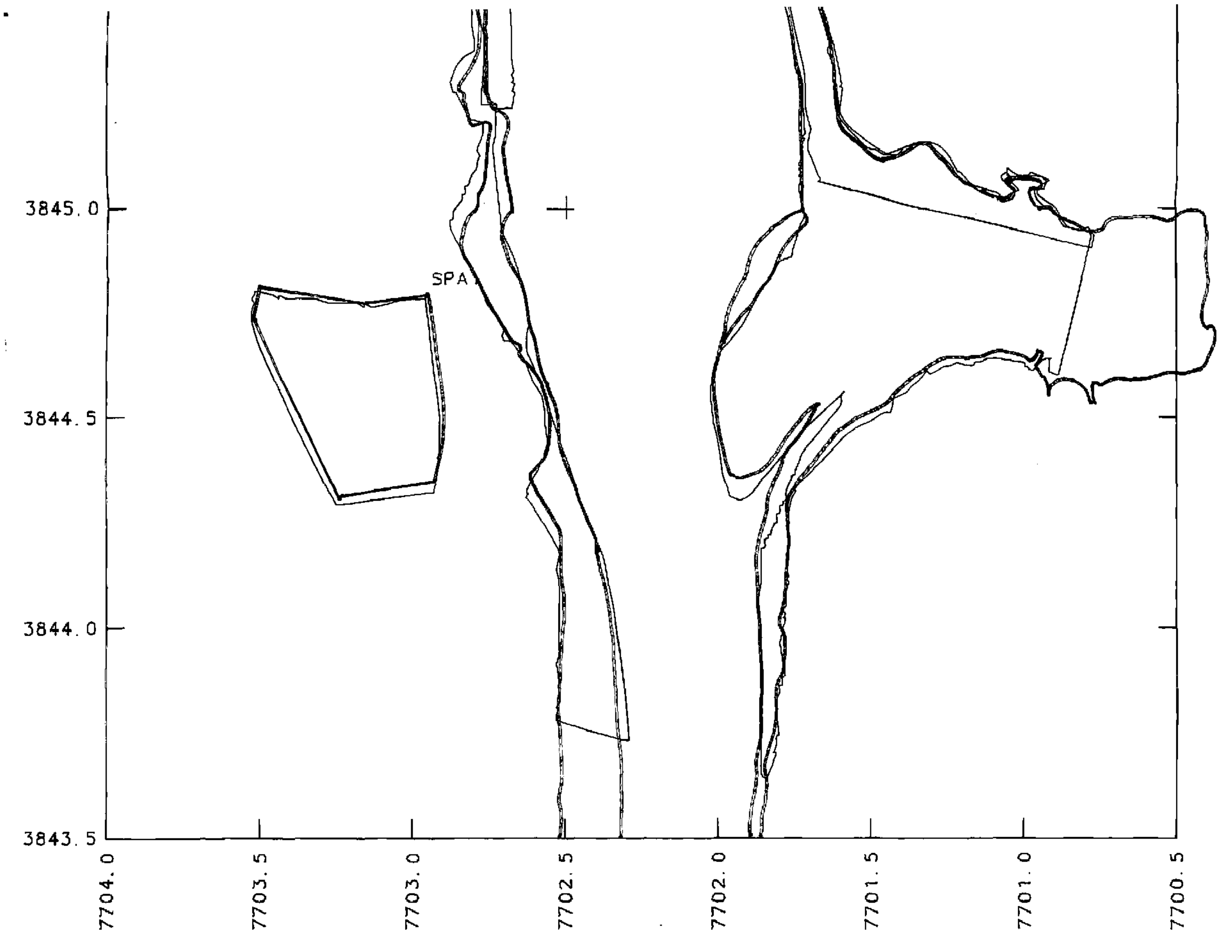
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Figure 34. MIPS SAV polygons (red) and VIMS photo-interpreted outlines of SAV beds (green) in the Bloodsworth Island, MD area, overlayed on NOS shoreline (1:24,000) (figure included in plastic page insert).

Fig 346.

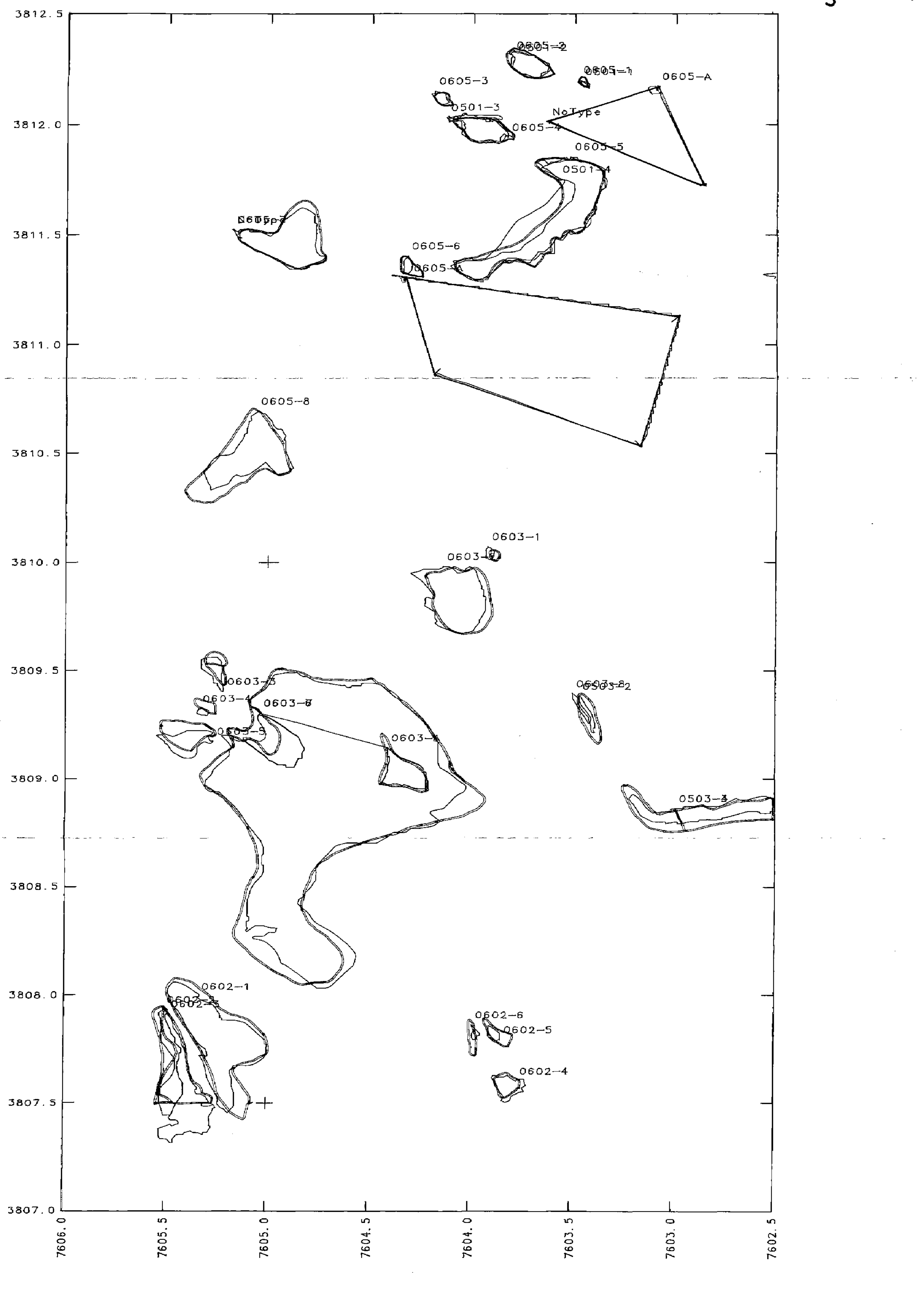
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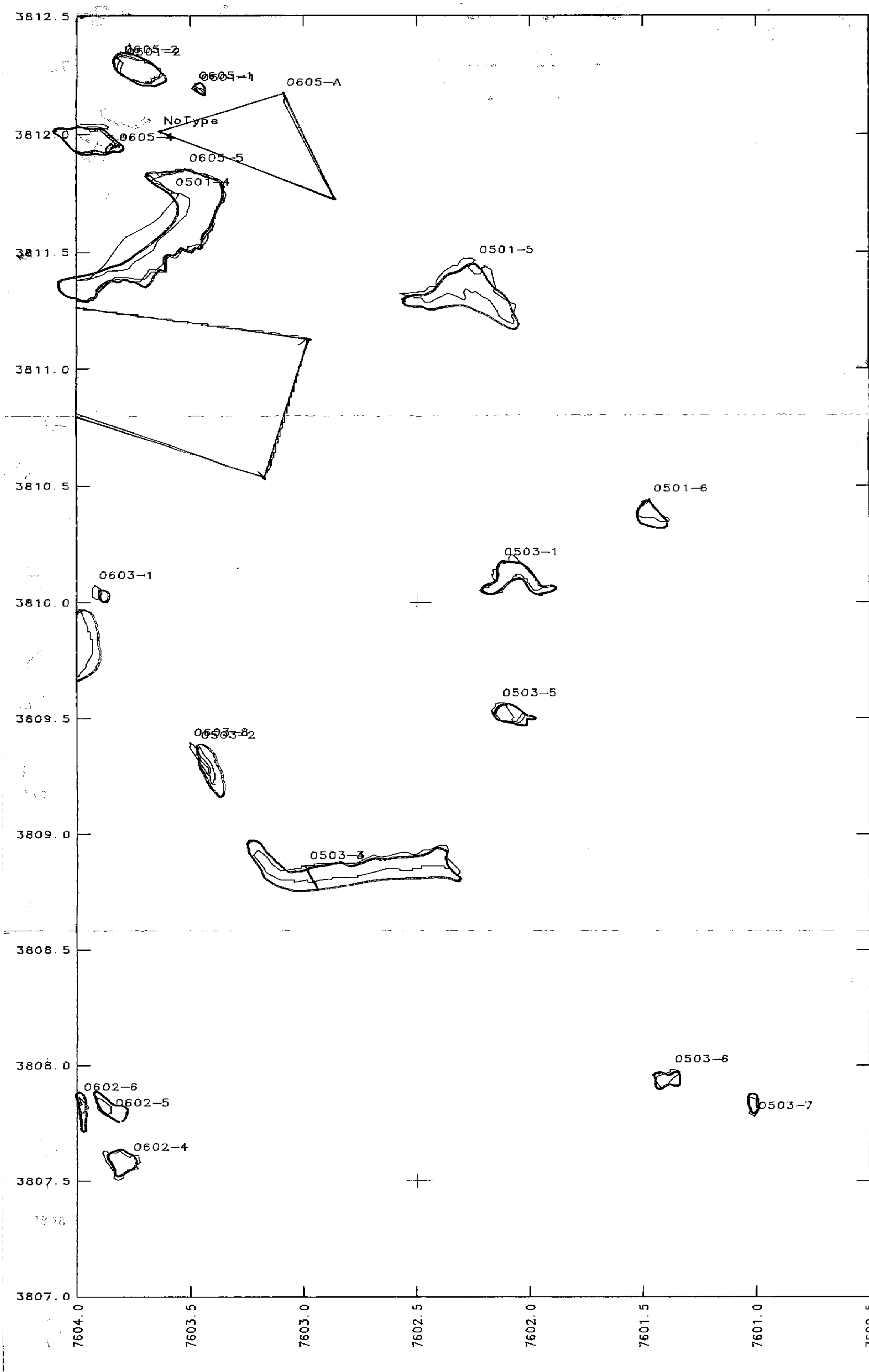
Fig 34a.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0603-1
0503-5
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0503-2
0503-3
0503-6
0503-7
0602-6
0602-5
0602-4
3812.5
3812.0
3811.5
3811.0
3810.5
3810.0
3809.5
3809.0
3808.5
3808.0
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7602.0
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7601.0
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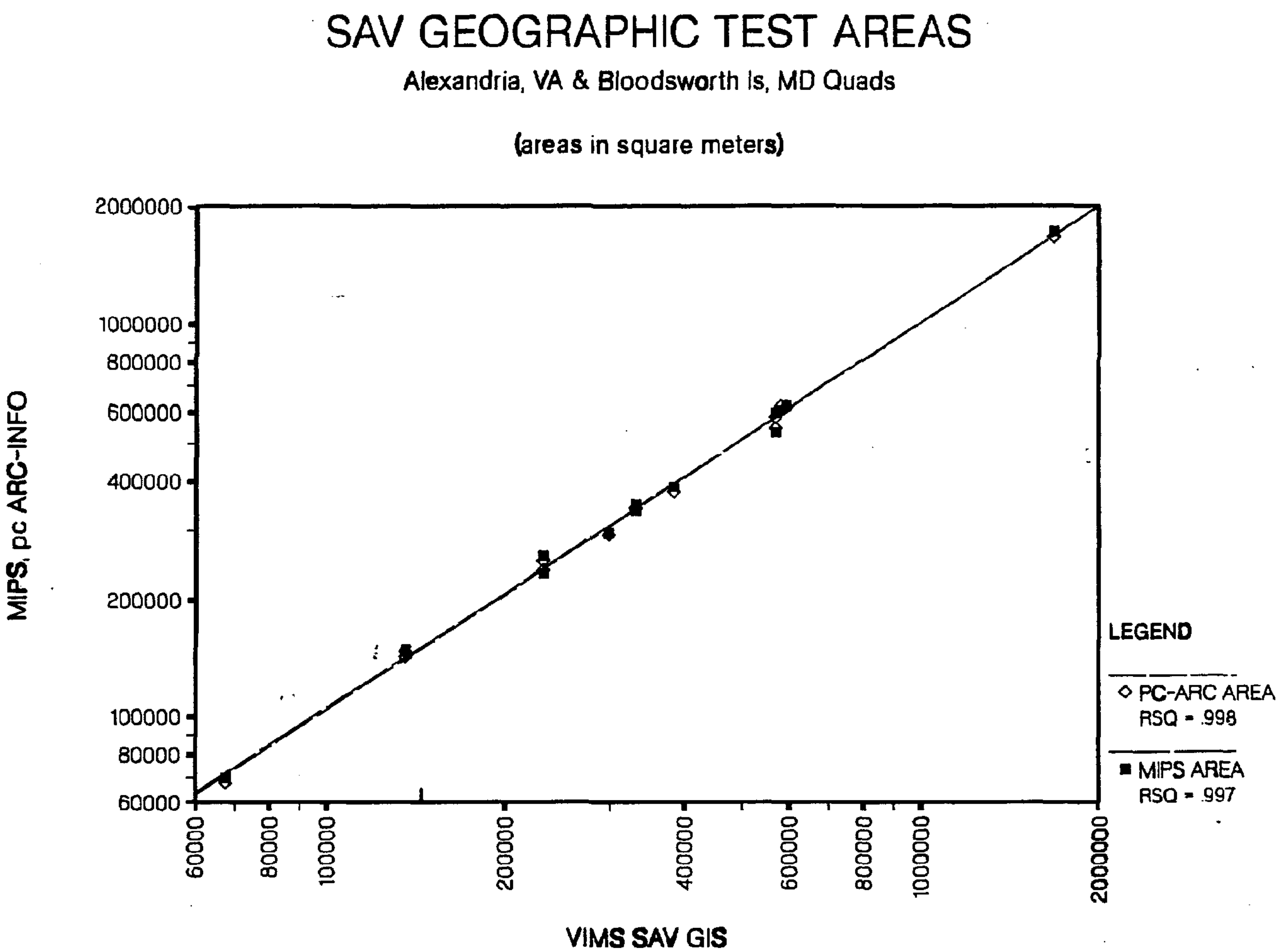

Figure 35. Scatterplot of MIPS and pc ARC-INFO derived geographic test area measurements versus VIMS SAV GIS derived geographic test area measurements (MIPS vs. VIMS - solid box, pc ARC-INFO vs. VIMS - hollow diamond).

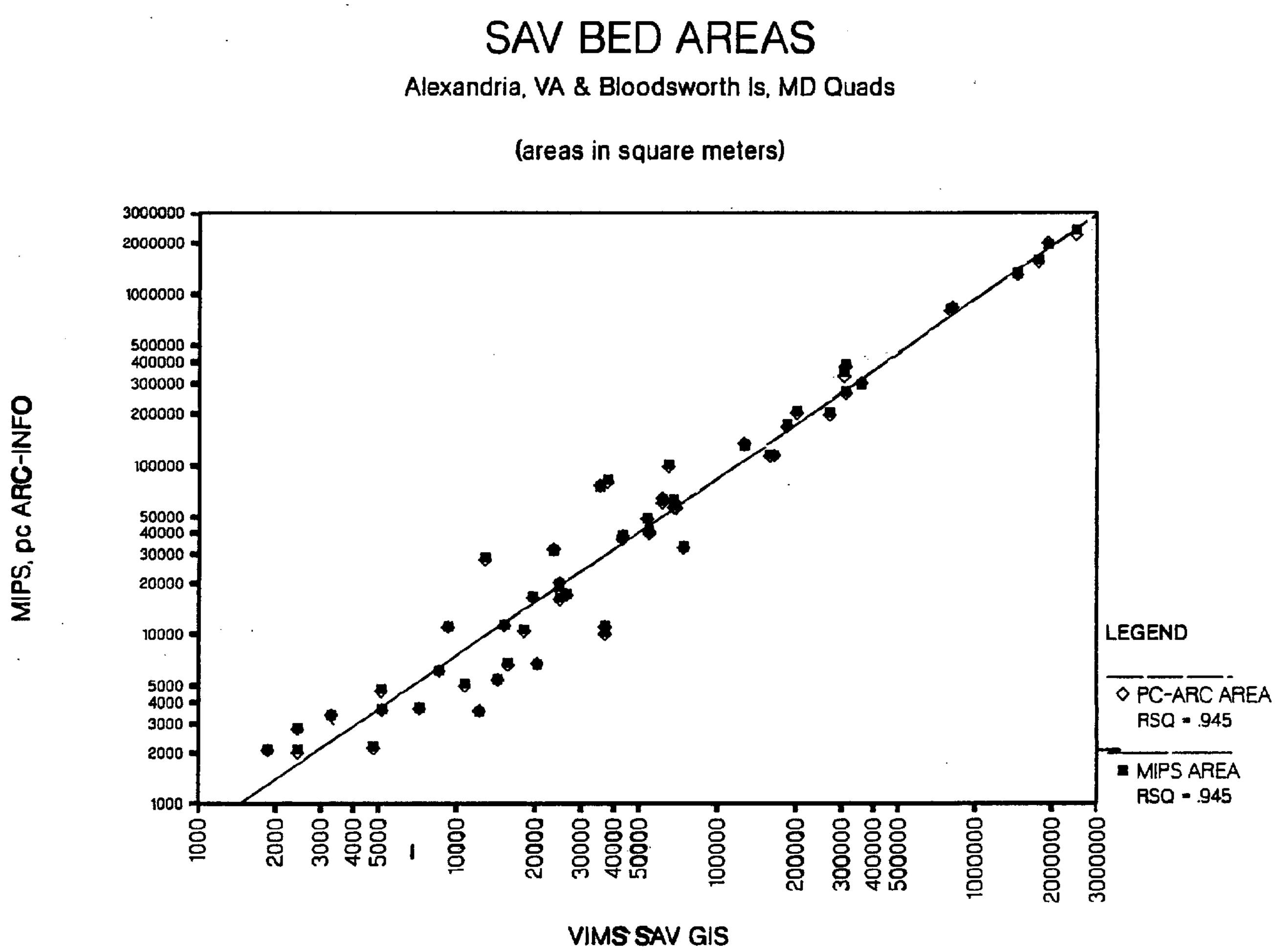

Figure 36. Scatterplot of MIPS and pc ARC-INFO derived SAV bed area measurements versus VIMS SAV GIS derived SAV bed area measurements (MIPS vs. VIMS - solid box, pc ARC-INFO vs. VIMS - hollow diamond).

Appendix A

MIPS Menu Listing

(after Ghormley, 1989)

MIPS menu listing

This section includes a complete listing of the MIPS menus for version 2.3. Menu selections for the main menu show in bold and large font size. Second-level menu choices show in bold at the regular font size. You can print a copy of the menus with the external LISTMENU utility from the MIPS subdirectory at the DOS prompt.

1 DISPLAY	**Create color or black and white displays**
1 RASTER	**Orthogonal display of 1, 2 or 3 rasters**
2 3D VIEW	**Perspective display of 2, 3 or 4 rasters**
1 RASTERS	Select a raster and all parameters & display
2 BATCH	Batch process a series of shots of the current file
3 VECTOR	**Display vector data**
4 3D VECTOR	**Display vector data**
1 VECTOR	Select a vector file & viewpoint and display
2 METHOD	Select a display method
3 VIEWPOINT	Select a viewpoint
4 LIGHT	Select a lightsource
5 MISC	Select miscellaneous display parameters
6 RECALC	Recalculate scaling and display
5 CONTRAST	**Perform contrast stretching and color balancing**
6 EDIT COLORS	**Create and edit pseudo-color tables**
1 CREATE/EDIT	Create or edit pseudo-color table for a raster
2 COPY COLORS	Copy pseudo-color table from one raster to another
3 COMPRESS	Compress color table by removing duplicates
7 COMPOSITE	**Create composite color raster from 3 rasters**
1 8-BIT	Create 8-bit composite color raster by optimization process
2 16-BIT	Create 16-bit composite color raster using 5-5-5 method
2 INTERPRET	**Manual and automated interpretation of rasters**
1 RASTER STAT	**Compute and display statistical information using rasters**
1 STATISTICS	Display standard statistics about raster data
2 HISTOGRAM	Compute frequency of occurrence of values in a raster
3 CORRELATE	Compute and display correllations between rasters
1 COMPUTE	Compute and display correllation between two rasters
2 DISPLAY	Display previously computed correlation between two rasters
2 VECTOR	**Perform statistical interpretations on vector data**
1 POLYGON	Display information about vector polygons(s)
2 HOME RANGE	Compute "home range" polygons using vector point data
1 MIN POLYGON	Compute home range using modified minimum polygon method
2 HARMONIC	Compute home range using harmonic mean method
3 FOURIER	Compute home range Fourier transform method
3 INTERSECT	Intersect two vector sets to create a new vector set.
1 COMPLETE	Completely intersect two vector sets
2 PARTIAL	Output only the polygons inside other polygons
3 CONVOLVE	**Compute a convolution on a single raster**
1 FILTER	Filter rasters
2 SURFACE	Compute slope, aspect and shading for an elevation raster
4 COMBINE	**Perform cell-by-cell transforms and combinations of rasters**
1 USER DEFINE	Perform user-defined transformation on rasters
2 ALGEBRAIC	Algebraic combinations of rasters
1 ADD	Add pairs of rasters

2 SUBTRACT	Subtract pairs of rasters
3 MULTIPLY	Multiply pairs of rasters
4 DIVIDE	Divide pairs of rasters
5 OFFSET	Add a constant to a raster
6 SCALE	Multiply a raster by a constant
3 LOGICAL	Cell-by-cell logical combinations of rasters
1 THRESHOLD	Threshold rasters
2 THRESH GREY	Separate colors from grey
3 EXTR-COLOR	Extract selected color by thresholding
4 RANGE	Select values within specified range
4 COLOR	Color transformations of rasters
1 RGB->HIS	Transform Red-Green-Blue to Hue-Intensity-Saturation
2 HIS->RGB	Transform Hue-Intensity-Saturation to Red-Green-Blue
3 RGB->CMY	Transform Red-Green-Blue to Cyan-Magenta-Yellow [i/d]
4 CMY->RGB	Transform Cyan-Magenta-Yellow to Red-Green-Blue [i/d]
5 INDICES	Predetermined special transformations for satellite images
1 MSS	Indices specific to Landsat Multispectral Scanner imagery
1 ND	Normalized Difference Index (B-A)/(B+A)*scale
2 TVI	Transformed Vegetation Index
3 LAI	Leaf Area Index
4 KAUTH	Kauth greeness/brightness index
5 BRYANT	Jack Bryant dimensional reduction
2 TM	Indices specific to Landsat Thematic Mapper imagery
1 ND	Normalized Difference Index (B-A)/(B+A)*scale
2 TVI	Transformed Vegetation Index
3 TASSLED CAP	Kauth tassled cap (greenness/brightness/wetness) index
6 PRINC-COMP	Perform principle components analysis/reduction on rasters
7 CONTRAST	Process a raster through a contrast table to make a new raster
5 FOURIER	**Perform cell-by-cell transforms & combinations of rasters**
1 FORWARD FFT	Compute Fourier Transform for a raster
2 INVERSE FFT	Compute Inverse Fourier Transform
6 ON-SCREEN	**On-screen interpretation of images**
1 FEATURE MAP	Perform interactive on-screen mapping of features
1 SELECT AREA	Select portion of displayed image or raster to analyze
2 CATEGORY	Define land use or other category overlay
3 CLASSIFY	Classify areas
4 TRANS LABEL	Transfer labeling info from vector polygon overlay
5 PROCESS	Perform final processing and store results
6 VECTORIZE	Convert feature map output raster to vector polygons
7 EDIT TEXT	Edit text files with MIPS editor
2 COLOR-CODE	Color code black and white rasters
1 CREATE/EDIT	Create or edit pseudo-color table for a raster
2 COPY COLORS	Copy pseudo-color table from one raster to another
3 COMPRESS	Compress color table by removing duplicates
3 RASTER	Interpret rasters by drawing on screen
4 VECTOR	Interpret vectors by drawing over rasters
5 SELECT AREA	Select portion of currently displayed image to analyze
7 SEMIAUTO	**Semiautomated interpretation using preidentified features**
1 MAX-LIKE	Maximum likelihood classification
1 CLASSIFY	Maximum-Likelihood classification
2 SETUP BATCH	Prepare batch classification
3 RUN BATCH	Run previously created batch classification
2 STEPWISE	Stepwise linear classification
1 CLASSIFY	Stepwise linear classification

2 SETUP BATCH	Prepare batch classification
3 RUN BATCH	Run previously created batch classification
3 SUITS	Suits classification
1 CLASSIFY	Classification by Suits' algorithm
2 SETUP BATCH	Prepare batch classification
3 RUN BATCH	Run previously created batch classification
4 PARIS	Jack Paris classification
1 CLASSIFY	Classification by Paris's algorithm
2 SETUP BATCH	Prepare batch classification
3 RUN BATCH	Run previously created batch classification
8 AUTOMATIC	**Automated interpretation with subsequent feature labeling**
1 SIMPLE	Simple distance-based cluster-seeking classification
2 K-MEANS	Classify-based on minimization of a performance index
1 CLASSIFY	K-MEANS classification
2 SETUP BATCH	Prepare batch classification
3 RUN BATCH	Run previously created batch classification
3 FZY C-MEANS	Classify using fuzzy C-means method
1 CLUSTERING	Fuzzy c_Means clustering
2 SETUP BATCH	Prepare batch clustering
3 RUN BATCH	Run previously created batch clustering
4 PARIS	Jack Paris unsupervised classification
1 CLASSIFY	Classification by Paris' method
2 SETUP BATCH	Prepare batch classification
3 RUN BATCH	Run previously created batch classification

3 PREPARE	**Prepare data from source materials**
1 RASTER	**Perform maintenance on raster data and related information**
1 COPY RASTER	Copy MIPS raster data between files
1 COPY	Copy raster and related data between files.
1 STANDARD	Copy multiple rasters with all related objects between files
2 GENERAL	Copy all or part of one raster to another
3 INSERT	Insert a smaller raster into a larger raster
4 16BIT->8BIT	Convert 16-bit (non-color) rasters to 8-bit rasters
5 COPY SCALE	Copy scale information from one raster to another
6 OTHER OBJS	Copy other raster-related objects between rasters
2 ENLARGE	Zoom rasters by cell replication
3 REDUCE	Shrink rasters by cell sampling
4 RE-ORIENT	Change raster orientation by rotating and inverting
1 ROT 90° CW	Rotate rasters 90 degrees clockwise
2 ROT 90° CCW	Rotate rasters 90 degrees counter-clockwise
3 ROTATE 180°	Rotate rasters 180 degrees
4 FLIP HORZ	Invert rasters horizontally
5 FLIP VERT	Invert rasters vertically
5 CREATE	Create new empty raster
2 EDIT-RASTER	Edit raster data interactively on-screen
3 MERGE	Merge multiple rasters into a single raster
1 TILE	Tile multiple parallel rasters into a single raster
1 TILE	Tile rasters
2 SETUP BATCH	Prepare batch file(s)
3 RUN BATCH	Run a previously prepared batch file
2 MOSIAC	Mosaic non-parallel rasters registered to a map projection
1 MOSAIC	Mosiac calibrated rasters

2 SETUP BATCH	Prepare batch mosaic raster file(s)
3 RUN BATCH	Run previously created batch mosaic raster file(s)
4 REGISTER	Calibrate raster to map projection, raster or vector
1 MANUAL	Calibrate to map projection by manually entering control points
1 CALIBRATE	Calibrate raster data to map projection
2 COPY CALIB	Copy map projction informatn from one raster to another
2 TO RASTER	Register one raster to another and trim
3 TO VECTOR	Calibrate to map projection by overlaying vector
1 CALIBRATE	Calibrate raster data to map projection
2 COPY CALIB	Copy map projction informatn from one raster to another
4 CHANGE PROJ	Change map projection for a raster
5 EXTRACT	Extract portion of calibrated raster using map boundaries
1 DISPLAY	Display single raster variable from specified coordinates
2 EXTRACT	Extract one or more raster variables to work file
5 RESAMPLE	Geometrically alter rasters by rescaling, rotating or warping
1 LINEAR	Perform linear rescaling and rotation of rasters to any angle
1 ALL-INPUT	Resample entire input raster to output file
2 SET-OUTPUT	Specify output size and position within input raster
3 SETUP BATCH	Setup parameters to run batch job later
4 RUN BATCH	Run previously setup batch jobs
2 PIECEWISE	Warp raster to match pre-defined piecewise-lin calibr
1 WARPRAST	Warp raster(s) by control point registration information
2 SETUP BATCH	Prepare batch warp rast file(s)
3 RUN BATCH	Run previously created batch warp raster(s)
3 POLYNOMIAL	Warp raster to match pre-determined polynomial fit
1 WARPRAST	Warp raster(s) by control point registration information
2 SETUP BATCH	Prepare batch warp rast file(s)
3 RUN BATCH	Run previously created batch warp raster(s)
4 BY MAP	Extract poriton of calibrated raster using map boundaries
1 DISPLAY	Display single raster variable from specified coordinates
2 EXTRACT	Extract one or more raster variables to work file
6 COLOR	Raster color manipulation tool
1 COMPOSITE	Create composite color raster from 3 separate rasters
1 8-BIT	Create 8-bit composite color rast by optimization process
2 16-BIT	Create 16-bit composite color raster using 5-5-5 method
2 COMP->COMP	Reduce number of colors in 8-bit composite color raster
3 COMP->RGB	Convert composite color raster to 3 separate rasters
7 GRAY VALUES	Calibrate raster cell gray levels to a user-defined scale
2 RAST->VECT	**Convert MIPS raster data to vector data**
1 THRESHOLD	Threshold 8-bit raster data to convert to binary
1 THRESHOLD	Threshold rasters
2 THRESH GREY	Separate colors from grey
3 EXTR-COLOR	Extract selected color by thresholding
4 RANGE	Select values within specified range
2 DEFINE TYPE	Create polygon type list to use in raster/vector conversion
3 LABEL AREAS	Assign labels to polygons within raster
4 EDIT-RASTER	Edit binary raster data
5 THIN-RASTER	Thin binary raster data
6 AUTO-LINE	Automatically convert thinned raster line data to vectors
7 SOLID-BOIUND	Automatic boiundary vectorization of solid/filled areas
8 CONTOURS	Compute vector contours from an elevation raster
3 VECTOR	**Perform maintenance on vector data and related information**
1 COPY VECTOR	Copy MIPS vector data between files
1 COPY VECTOR	Copy an RVF vector object

2 EXTRACT	Extract a portion of a vector object
3 COPY OTHER	Copy sub-objects from one vector to another
2 MERGE VECTS	Merge multiple vector sets into one
3 VECT POLYS	Process vector line data into polygon data
4 FROM DBASE	Build a vector set with a node for ea record in a database
5 EDIT	Edit vector data
1 FULL VECTOR	Edit all vector set data overlaying on raster if desired
2 NODE SYMBOL	Create or edit symbols for vector nodes
3 DEFINE TYPE	Create vector node, line and polygon type lists
4 LABELS	Edit vector node/line/polygon labels
6 THIN-VECT	Thin vectors
7 MAP PROJ	Calibrate raster to map projection, raster or vector
1 MANUAL	Calibrate to map projection by manually entering control points
1 CALIBRATE	Calibrate vector data to screen, raster or map
2 COPY CALIB	Copy map projection calib from one vect set to another
2 OVERLAY	Calibrate vector data to by overlaying on current display
1 CALIBRATE	Calibrate vector set directly to a raster
2 COPY CALIB	Copy map proj calibration from one vect set to another
3 WARP VECTOR	Warp vector to match pre-defined non-linear calibration
1 POLYWARP	Warp or d-warp vector(s) by polynomial transformation
2 TRIWARP	Warp or d-warp vector(s) by piecewise linear transfm
4 CHANGE PROJ	Change map projection for a vector set
8 INTERSECT	Intersect two vector sets to create a new vector set
1 COMPLETE	Completely intersect two vector sets
2 PARTIAL	Output only the polygons inside other polygons
9 EXTRACT LAB	Extract labels by geographic position
0 FIX VECTORS	Process vector data to remove data errors
4 VECT->RAST	**Convert vector data to raster data**
1 FLAT	Convert 2-D vector data to a raster
2 SURFACE	Compute elevation raster from 3-D vector point data
1 POLYNOMIAL	Polynomial surface fitting
2 RECTANGLE	Piecewise rectangle survace fitting
3 TRIANGLE	Piecewise triangulation surface fitting
5 DATABASE	**Create and edit database information**
1 LINK DBASE	Create a link to an existing database file (non-MIPS fmt)
2 EDIT LAYOUT	Customize the location of database fields in the editor
3 BUILD	Build a vector set with a node for everty record in database
4 ATTACH	Attach database of node/line/poly types to a vector or rast
5 EDIT DBASE	Display and edit an existing database (without graphics)
6 ANOTHER	Create another database from an existing one
7 NEW	Create a new database totally from scratch
6 IMPORT	**Convert non-MIPS data to MIPS format**
1 RASTER	Import raster data into MIPS from other disk file formats
1 STANDARD	Convert standard formats to MIPS format
2 GENERIC	Perform generic format conversion
3 CREATE/EDIT	Create or edit generic format description
4 LINK RASTER	Link to external raster files
5 RUN SCRIPT	Run a script file defining files to be imported
2 VECTOR	Import vector data into MIPS from other disk file formats
1 DXF	Import from CAD DXF (Autocad) format
2 DXF 3D	Import from CAD DXF (Autocad) format
3 USGS DLG	Import standard format ASCII Digital Line Graph data
1 STANDARD	Import standard format ASCII Digital Line Graph data
2 OPTIONAL	Import "Optional Format" ASCII Digital Line Graph data

3 BINARY	Import BINARY Digital Line Graph data
4 MOSS	Import Map Overlay and Statistical System data
1 IMPORT MOSS	Import MOSS data into MIPS
2 CONV POLYS	Convert previously imported data by removing redundant lines
3 DEPTH SORT	Depth-sort polygons to locate islands
5 ARC-INFO	Import Arc/Info vector formats
1 GENERATE	Import Arc/Info "Generate" format data
2 COVERAGE	Import PC Arc/Info "Coverage" format
6 GRASS	Import GRASS vector format
7 TIGER	Import U.S. Census Bureau TIGER format data
8 POINT DATA	Import 2-D (x,y) and 3-D (x,y,z) point data into MIPS format
3 MISC	Import miscellaneous data into MIPS
1 OPT	Import old .OPT files into MIPS
4 FROM TAPE	Import MIPS rasters from magnetic tapes
1 FULL SCENE	Create raster(s) for entire satellite scenes on disk
1 MSS-EDIPS	Create full-scene rasters from MSS-EDIPS format tapes
1 COPY SCENE	Copy entire MSS scene from tape to disk
2 MAKE HEADER	Create RVF header file for previously read scene
2 TM-1600TIPS	Create 1/4 scene rasters from TM-TIPS 1600 bpi tapes.
1 COPY SCENE	Copy entire TM 1/4 scene from tape to disk
2 LINK FILES	Link to previously extracted file using original tape
3 TM-1600	Create 1/4 scene rasters from TM-TIPS converted from6250 tape
1 COPY SCENE	Copy entire TM 1/4 scene from tape to disk
2 LINK FILES	Link to previously extracted file using original tape
4 TM-6250TIPS	Create 1/4 scene from TM-TIPS 1/4 scene 6250 bpi tape.
1 COPY SCENE	Copy entire TM 1/4 scene from tape to disk
2 LINK FILES	Link to previously extracted file using original tape
5 SPOT	Create full-scene raster(s) from SPOT image tapes.
1 COPY SCENE	Copy entire SPOT scene from tape to disk
2 MAKE HEADER	Create header file for previously read scene
2 SATELLITE	Extract subimage from satellite scene into MIPS rasters
1 MSS	Extract from Multispectral Scanner Imagery
1 STANDARD	Extract from standard LGSOWG format tapes
1 LAT/LON	Extract by geographic map location
2 LIN/COL	Extract by selected line/column ranges
2 USA-EDIPS	Extract from EDIPS format tapes
1 LAT/LON	Extract by geographic map location
2 LIN/COL	Extract by selected line/column ranges
3 USA-X	Extract from pre-1979 X-format tapes
1 LAT/LON	Extract by geographic map location
2 LIN/COL	Extract by selected line/column ranges
4 CANADIAN	Extract from Canadian format tapes
1 LAT/LON	Extract by geographic map location
2 LIN/COL	Extract by selected line/column ranges
2 TM	Extract from Thematic Mapper Imagery
1 TIPS-1600	Extract from TIPS format 1600 bpi quarter scene tapes
1 LAT/LON	Extract by geographic map location
2 LIN/COL	Extract by selected line/column ranges
2 6250-1600	Extract from tapes converted from 6250 bpi to 1600 bpi
1 LAT/LON	Extract by geographic map location
2 LIN/COL	Extract by selected line/column ranges
3 TIPS-6250	Extract from TIPS format 6250 bpi quarter scene tape
1 LAT/LON	Extract by geographic map location
2 LIN/COL	Extract by selected line/column ranges

4 SCROUNGE	Extract from original full-scene "scrounge" format
1 LAT/LON	Extract by geographic map location
2 LIN/COL	Extract by selected line/column ranges
2 MEDICAL	Import medical images into MIPS rasters
1 MRI-GE	Convert MRI images from GE archive tapes
2 GE CT-9800	Extract images from GE CT model 9800 tapes
7 EXPORT	**Export MIPS data to other formats**
1 RASTER	Convert MIPS rasters to other disk file formats
1 STANDARD	Export to standard raster formats
2 GENERIC	Export raster data to user-defined format
3 CREATE/EDIT	Create or edit generic format description
2 VECTOR	Convert MIPS vector data to other disk file formats
1 DXF	Export to AutoCAD DXF format
2 DXF 3D	Export 3-D vector data to AutoCAD DXF format
3 DLG-OPT	Export "Optional Format" ASCII Digital Line Graph data
4 MOSS	Export to Map Overlay and Statistical System (MOSS) format
5 ARC-INFO GEN	Export Arc/Info "Generate" format data
6 PC ARCINFO	Export PC Arc/Info "Coverage" format
7 GRASS	Export GRASS vector format
8 TIGER	Export U.S. Census Bureau TIGER format
8 SCAN	**Digitize raster data using hardcopy scanner**
1 PARAMETERS	Set scanning paramters
2 SCAN->DISP	Scan and display
3 SCAN->FILE	Scan and save in file
9 VIDEO	**Digitize video images from camera or VCR**
1 CAPTURE	Display and capture images from video source
2 SAVE RASTER	Save captured image as single or multi-band raster
3 SAVE TARGA	Save captured image in TARGA format
4 SUPPORT	**User and programmer utilities**
1 MIPS	**Display and alter contents of MIPS files**
1 NUM-RASTER	Numerically display contents of rasters
2 NUM-HISTO	Numerically list a histogram
3 NUM-CONTR	Numerically list a contrasting table
4 NUM-PSEUDO	Numerically list a pseudo-color table
5 NUM-COLORS	Numerically list a color assignment table
6 SPLIT RAST	Split raster datasets into multiple disk-sized pieces
1 SPLIT RASTER	Split a set of rasters into several pieces
2 RECOMBINE	Recombine all or part of a previously split raster
7 EDIT-CURSOR	Edit cursor shapes
2 EDIT TEXT	**Edit text files with MIPS editor**
3 TAPE	**Tape utility functions**
1 GENERAL	Transfer files to and from general (unlabeled) tapes
1 SCAN-TAPE	Scan unknown tape for general layout
2 TAPE->DISK	Copy tape file(s) to disk
3 DISK->TAPE	Copy disk file(s) to tape
4 SETUP	Set up transfer parameters
5 BACKUP	Backup disk files to tape
6 RESTORE	Restore disk files from tape
7 REWIND	Rewind tape to beginning
8 UNLOAD	Unload tape from drive
9 RE-TENSION	Make tape tension even, skip to end of tape, then rewind
0 INITIALIZE	Prepare new tape for use or erase old tape

2 STD-ANSI	Transfer files to and from ANSI standard label tapes
1 LIST-FILES	List files on tape
2 TAPE->DISK	Copy tape file(s) to disk
3 ALL->DISK	Copy all tape files to disk
4 REWIND	Rewind tape to beginning
5 UNLOAD	Unload tape from drive
3 STD-IBM	Transfer files to and from IBM standard label tapes
1 LIST-FILES	List files on tape
2 TAPE->DISK	Copy tape file(s) to disk
3 ALL->DISK	Copy all tape files to disk
4 REWIND	Rewind tape to beginning
5 UNLOAD	Unload tape from drive
4 SLIDE SHOW	**Create or play back "slide shows"**
2 RUN	Execute a slide show
3 EDIT	Create or modify a slide show definition
5 HARDCOPY	**Output hardcopy**
1 PRINT	**Dithered print of display screen or files**
1 SCREEN	Print the display screen
2 RASTER	Print a MIPS raster file
3 TARGA	Print a TARGA file
4 DITHERED	Print a dithered raster saved earlier
5 PRF FILE	Print a "Print File" (*.PRF) saved earlier
2 FILM	**Film recorder output from display screen or files**
1 SCREEN	Print the display screen
2 RASTER	Print a MIPS raster file
3 TARGA	Print a TARGA file
4 DITHERED	Print a dithered raster saved earlier
5 PRF FILE	Print a "Print File" (*.PRF) saved earlier
3 PLOT	**Plot vector data**
1 PLOT RVF	Plot a MIPS vector file
2 FROM FILE	Plot a Plot file
4 ANNOTATE	**Add predefined annotations to print rasters**
6 RETRIEVE	**Retrieve previously prepared data sets**
1 HYPER-BASE	**Access the hyper-index database**
2 LAT/LON	**Select area by manually specifying map bounderies**
1 DISPLAY	Display single raster variable from specified coordinates
2 EXTRACT	Extract one or more raster variables to work file
3 DATABASE	**Retrieve information from external database by lat/lon**

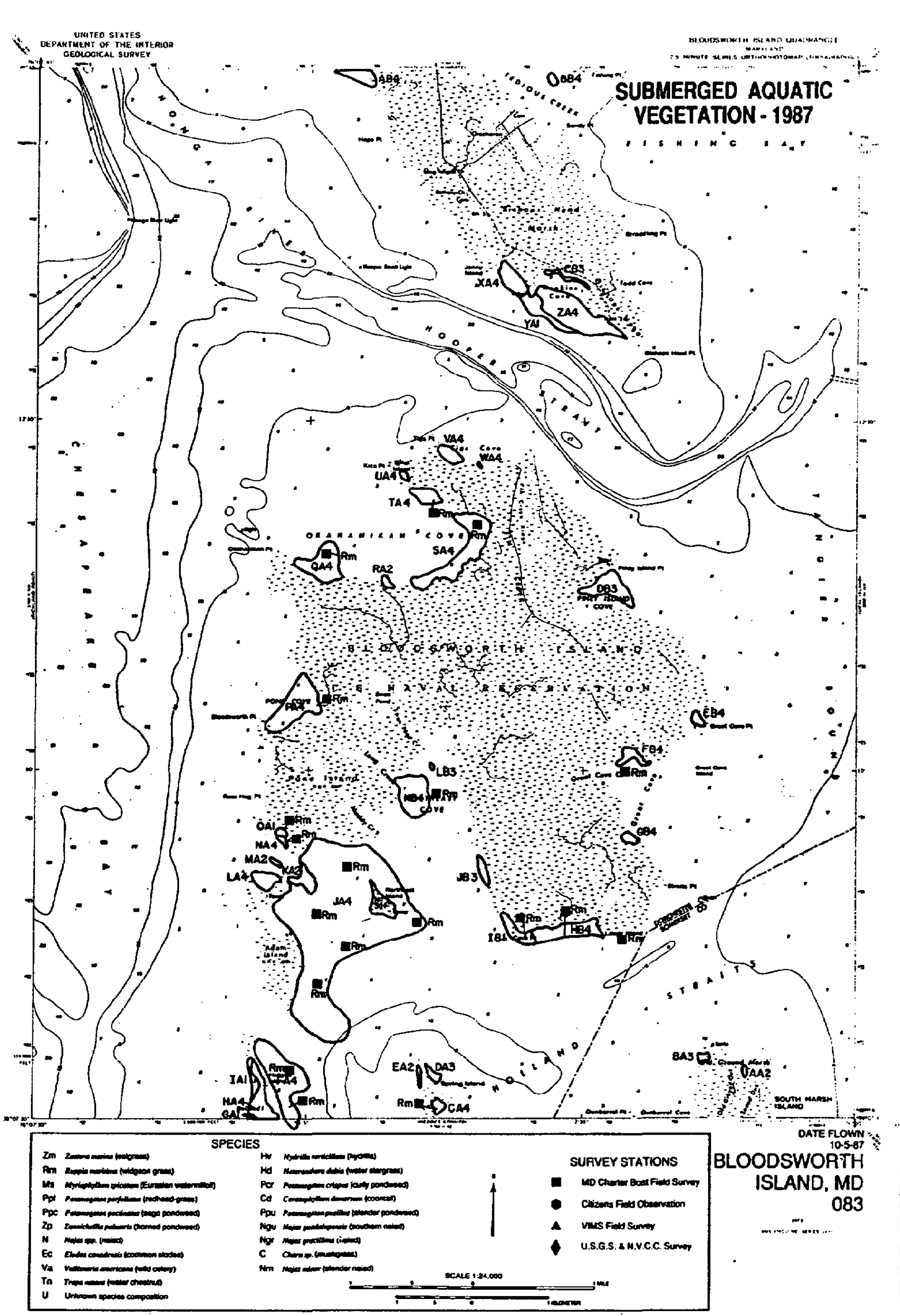

Figure 24. USGS Bloodsworth Island, MD, 1973, 7.5 minute, orthophotomap (topographic), 1:24,000, mylar base, quad map edition with SAV beds and geographic test areas labeled and outlined in bold ink (after Orth et. al, 1989).