ANALYSIS OF HISTORICAL DISTRIBUTION OF SUBMERGED AQUATIC VEGETATION (SAV) IN THE YORK AND RAPPAHANNOCK RIVERS AS EVIDENCE OF HISTORICAL WATER QUALITY CONDITIONS

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Executive Summary

Historical black and white format photographs at scales of approximately 1:20,000, dating from 1952 to 1956 were used to delineate the maximum coverage of SAV in the study region. Coverage of photography from decades before and after this period were found to generally to be of poorer quality and show less SAV presence. Photo-interpretation of the aerial photographs was accomplished using a head-up, on-screen digitizing system at fixed image scale of 1:12,000 and followed as closely as possible the methods currently used to delineate SAV beds throughout the Chesapeake Bay as well as the delineation of historical SAV coverage for other region.

A total of 16,340 hectares of sub-tidal bottom in the western shore bay region between the James and Potomac Rivers including all of the York and Rappahannock Rivers were found to display SAV signatures. Of this total approximately 11,260 ha, or 69%, were determined to be growing at depths shallower than 1 m MLW (Mean Low Water), 4,200 ha or 26% between 1 m and 2 m MLW, and 884 ha or 5% at depths below 2 m MLW. Comparison of the historical depths of growth with that of photography taken in 1999 reveal a general decrease in maximum depth of growth of approximately 0.5m in many areas. The most upriver areas of the York and Rappahannock, where SAV no longer are found, had SAV bed signatures to 1 m MLW, while downriver areas and regions along the Chesapeake Bay had maximum depths or 2 m or more in some areas. Losses of vegetation have been much more extensive in the Rappahannock than the York. In 1999, in the lower York River (YRKPH) approximately 23% of the historical SAV coverage remained while only 1% remained in the lower Rappahannock (RPPMH). Areas along the bay shoreline had the highest proportion of remaining beds with bay segments CB6PH and MOBPH exceeding 50% of historical coverage.

Introduction

Throughout most regions of the Chesapeake Bay and its tributaries both direct and anecdotal evidence has indicated that large-scale declines of submerged aquatic vegetation (SAV) occurred in the late 1960s and early 1970s (Orth and Moore 1983a). These declines have been attributed to increasing amounts of non-point inputs of nutrients and sediments in the bay system resulting from development of the bay's shorelines and watershed (Twilley et al. 1985). Currently there are approximately 27,000 ha of SAV in Chesapeake Bay (Orth et al. 2000). Although it has been estimated that this is approximately 10% of the bay's historical SAV distribution, most comprehensive analyses have been based on 1971 or later aerial photography and the distributions of SAV prior to this time in many regions are not well known.

SAV is a highly valuable resource whose presence serves as an important indicator of local water quality conditions (Dennison et al. 1993). SAV growth and survival can be decreased by high levels of turbidity and nutrient enrichment, and because SAV beds are non-motile, their presence serves as an integrating measure of variable water quality conditions in local areas (Moore et al. 1996). Water quality requirements for SAV growth are particularly crucial as barometers of the health of the Chesapeake Bay environment because, unlike restoration requirements developed for various species of fish and shellfish, they are not impacted by direct human harvesting activities.

Because of the direct relationships between SAV and water quality, trends in the distribution and abundance of SAV over time are also very useful in understanding trends in water quality. Review of photographic evidence from a number of sites dating back to 1937 suggests that SAV, once abundant throughout the Chesapeake Bay system, have declined from historic levels and therefore water quality conditions may have similarly deteriorated (Orth and Moore 1983).

For example, areas with high currents and wave activity or sites where sediments are very high in organic content may not be suitable for SAV growth. Therefore targets for the geographical limits of SAV restoration have been based on documented evidence of previous SAV growth in the region since 1971 (Batiuk et al. 1992). However, we lack comprehensive knowledge of the historical, pre-1971 levels of SAV in Virginia's tributaries such as the York and Rappahannock rivers where there is some anecdotal evidence that SAV declines may have begun prior to 1970. Therefore SAV restoration goals for these rivers may underestimate the potential for SAV recovery. To develop reasonable SAV restoration targets in the York and Rappahannock Rivers and to formulate the strategies for achieving these targets, it is necessary to first identify the potential for SAV restoration. Identification of those areas with previous evidence of SAV growth is an important step in quantifying that potential.

Recently, a study funded through the Department of Conservation and Recreation completed the analysis and mapping of the historical distribution of submerged aquatic vegetation in the James River (Moore et al. 1999). This study found that, although the established Tier I restoration goal for the James River region was 107 ha, a total of 1,645 ha of SAV had been present in the James River during the 1930s and 1940s and that SAV formerly grew to depths of 2 m or more in some areas. Conversely, Tier II and Tier III restoration goals based upon projected SAV growth throughout the James to depths to 1 m and 2 m, are 16,560 ha and 24,811 ha, respectively. These restoration objectives that would require over 10 times the abundance of the historical SAV, while important, may never be achievable in this region. Therefore, more realistic, historically documented, restoration targets may be useful. The results provided in this report follow directly along with the previous work and together they provide a comprehensive analysis of SAV throughout most of Virginia's principal coastal tributaries.

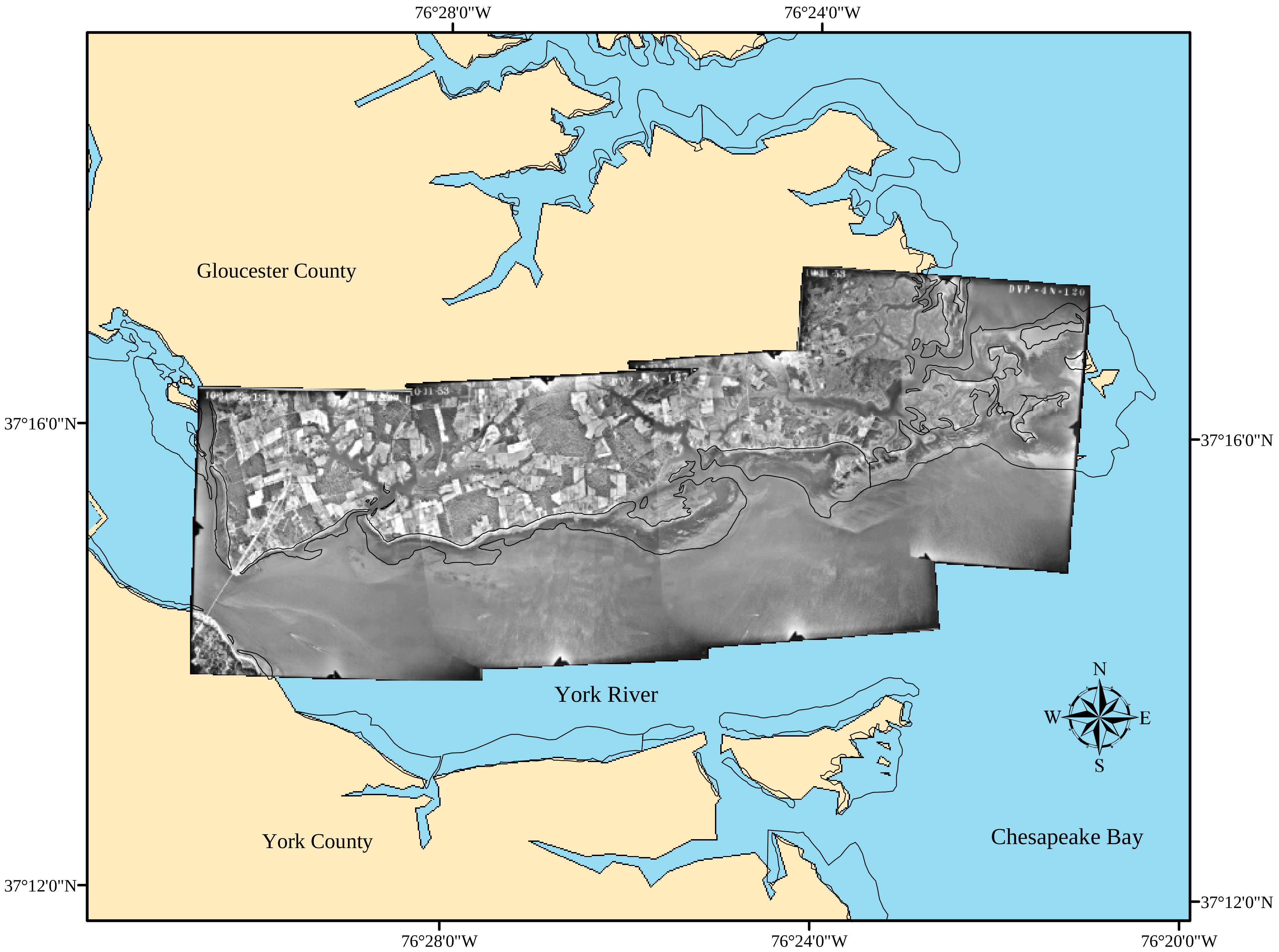
SAV communities are particularly suitable for identification through analysis of aerial photography from a variety of sources (Orth and Moore 1984). Although estuarine waters can be quite turbid, SAV are generally found growing in littoral areas where depths are less than one meter and their photographic signatures can be identified by experienced photo-interpreters. Although the absence of SAV on historical aerial photographs does not necessarily preclude SAV occurrence, SAV signatures are strong supporting evidence for the previous occurrence of SAV (Orth and Moore 1983b).

The objectives of this study were: 1) To search photo archives for imagery of the littoral zones in the tidal portions of the York and Rappahannock Rivers and the small coastal basins and embayments from “Old Point Comfort” at the mouth of the James River to “Smith Point” at the mouth of the Potomac River (Appendix 1) for evidence of SAV. These beds represent an historical, pre-decline benchmark of a healthy SAV community in these regions of the Chesapeake Bay and its tributaries. 2) To create a digital composite database of these photo-interpreted bed outlines and to quantify these historic SAV distributions using a computer-based GIS (Arc/Info).

Methods

Key photographic databases, including Va. Department of Transportation (VDOT), National Oceanic and Atmospheric Administration (NOAA), United States Department of Agriculture (USDA), United States Geological Survey (USGS), and the Virginia Institute of Marine Science (VIMS) archives as well as other published reports, were searched for photography and other information relative to SAV occurrence in the York and Rappahannock rivers prior to the decline in the early 1970s. Photographic databases ranging from the 1930s to the 1960s were searched by direct visits to view paper prints and color transparencies. Photographs that contained images of SAV were scanned and brought into the GIS as described below. Web-based USGS and NOAA databases were also searched online using a web browser. Photo-interpretation of the selected aerial photographs followed as closely as possible the methods currently used to delineate SAV beds throughout the Chesapeake Bay in the annual aerial SAV surveys (eg. Orth et al. 2000). Generally, high salinity SAV beds, which may have occurred in regions of the York and Rappahannock rivers where salinities are typically above 10 PSU, can be identified in the shallow, near shore regions by their characteristic bottom patterns and reflectance signatures. These patterns are similar to beds currently found in other regions of the lower bay. Figure 1 illustrates typical historical SAV signatures from high salinity beds at the mouth of the York River, on photography that was taken in April of 1953. Maximum seasonal biomass of high salinity SAV in this region would have occurred in late May to early July, therefore these images depict the vegetation near maximum standing crop. Low salinity and freshwater SAV beds generally have much darker signatures (Moore et al. 1999), which can sometimes be confused with other bottom features. However, low salinity and freshwater SAV beds currently occur in many regions of the Maryland portion of the upper Chesapeake Bay as well as some Maryland tributaries including the Potomac River. These SAV beds serve as a useful guide for photo-interpretation of historical photography of the upper York and Rappahannock. Historical observations, both qualitative and quantitative, of SAV in the region may sometimes be required to accurately determine whether the patterns exhibited on the photography are actually those of SAV beds. Maximum seasonal biomass for freshwater SAV

Figure 1. Typical Historical SAV Signatures on Photography of the Lower York River


76°28'0"W
76°24'0"W
Gloucester County
37°16'0"N
37°16'0"N
York River
N
W
E
S
York County
Chesapeake Bay
37°12'0"N
37°12'0"N
76°28'0"W
76°24'0"W
76°20'0"W

species typically occurs in late summer and early fall, therefore these images depict sparse, early season growth.

Initial screening of photographic prints was accomplished by viewing under a 10X magnification viewer. Each print was searched for SAV signatures, and the quality of the imagery for SAV delineation was estimated as “Good,” “Fair,” or “Poor.” Those prints that showed some evidence of SAV signatures were scanned at a resolution of 600 dpi and viewed using ERDAS Imagine™ image processing software.

The aerial photography that was determined to have SAV signatures was processed using a heads-up, on-screen digitizing system. The system improves accuracy by combining the series of images into a single geographically registered image permitting the final SAV interpretation to be completed seamlessly in a single step. In addition, the images are available digitally and can be printed along with the interpreted lines to show the precise character of the SAV beds.

The standard 9 in X 9 in, 1:24,000 scale black and white aerial photographs, which were scanned at a resolution of 600 dpi, formed pixels approximately one meter in width. This is the minimum resolution required to accurately delineate SAV beds and resulted in files that were approximately 30 megabytes in size. The scanned images were then transferred to a Windows 2000 workstation for registration using ERDAS Orthobase™ (ERDAS, Atlanta, Ga.). Horizontal control was taken from USGS digital orthophoto quarter quads (DOQQ) and USGS 1:24,000 scale topographic quadrangles. USGS DEMs for the region were merged and used for vertical control. The Orthobase™ software combined both sources of control with a set of common “tag” points that were identified on pairs of photos to generate a photogrammetric solution and orthorectify the images, producing a single geographically corrected product that was used for interpretation. The total RMS error for the solution varied among images from 2.6 meters to 4.1 meters with a mean of 3.5 meters.

SAV bed outlines were traced directly from the combined image displayed on the computer screen using ERDAS Imagine into an ArcInfo (ESRI, Redlands, Ca.) GIS polygon file. The image scale was held fixed at 1:12,000 and line segments for polygons characterizing the beds were set to be no shorter than 20 meters to maintain consistency with previous historical SAV surveys. The interpreted boundaries were drawn to include all visible SAV areas regardless of patchiness or density.

Results and Discussion

Acquisition of Historical Photography

A variety of pre-1971 historical aerial photographic images of the York and Rappahannock Rivers study region were located and reviewed, however the quality of the imagery for determination of SAV abundance ranged from good to poor. In general, a number of criteria must be met for acquisition of aerial photographs which are optimum for delineation of estuarine SAV (eg. Orth and Moore 1983a; Orth et al, 2000). These address tidal stage, plant growth stage, sun elevation, water and atmospheric transparency, wind, sensor operation, flight line plotting and film type. Most imagery used for historical SAV analyses was obtained for other purposes, usually land use or farming analyses, and therefore, while criteria for atmospheric conditions are usually met (eg. sun elevation, atmospheric transparency, etc.), those important for SAV delineation (eg. tidal stage, water transparency, plant growth stage) may not be met. In addition, while standard black and white, and color photographs are useful for SAV delineation (Orth et al. 1984) other film types such as infrared or color infrared photography, which effectively delineations upland vegetation, are less useful in delineating submerged vegetation because of the rapid absorption of the infrared wavelengths of sunlight in water.

In general, the most useful historical photography found in this study for delineation of SAV in the James River came from USDA. This photography acquired for land use and agricultural purposes was primarily black and white format at scales of approximately 1:20,000. The earliest photography is from USDA over-flights conducted during 1936 and 1937. However much of this 1930s photography was found to show less SAV coverage that similar photography from the 1950s. Qualitatively in many areas the difference appeared to be related to overall poorer atmospheric and water clarity conditions making SAV less apparent. In many other areas it appeared that the SAV were generally less abundance during the periods of the overflights during the 1930s compared to the 1950s. Slight seasonal differences may have also been a factor, however, both sets of photography were taken during the approximate middle of the principal SAV growing season (April-October). Given these differences, the 1950s series of USGS photographs ranging from 1952 to 1956 were chosen to delineate maximum coverage of SAV in the study region.

Historical SAV Distribution

A total of 16,340 hectares of sub-tidal bottom in the York and Rappahannock River study area were found to display SAV signatures prior to 1971 (Table 1). Photo-interpreted historical SAV bed outlines are presented for each CBP bay segment in Appendix 1 and for each 7.5-minute series USGS Quadrangle in Appendix 2. Of this total approximately 11,260 ha. or 69% were determined to be growing at depths shallower than 1m MLW (depths based on bathymetric contours developed by CBP from NOAA soundings data), 4,200 ha. or 26% between 1 and 2 m, and 884 ha. or 5% at depths below 2m. Interestingly, the three bay segments with the highest proportions of historical SAV growing below 2m depths (and therefore the greatest leaf surface light availability or PLL) were CB5MH, CRRMH and RPPMH. These segments include the SAV regions between the Rappahannock and the

Table 1. Historical SAV Distibution for Each CBP Bay Segment in Study Area (Total and by Depth Zone Below MLW)

BAY SEGMENTS	**DEPTH ZONES**						**TOTAL HISTORICAL (HECTARES)**
	0 TO 1 METERS		1 TO 2 METERS		> 2 METERS		
	HECTARES	*% TOTAL*	*HECTARES*	*% TOTAL*	*HECTARES*	*% TOTAL*	
CB6PH	410.88	80.1	100.44	19.6	1.5	0.3	512.82
CB5MH**	1,277.34	40.8	1,508.84	48.2	345.75	11.0	3,131.93
CRRMH	209.84	80.1	34.21	13.1	17.95	6.9	261.99
RPPMH	2,226.65	70.4	714.39	22.6	222.45	7.0	3,163.49
RPPOH	nd*	nd	nd	nd	nd	nd	nd
RPPTF	nd	nd	nd	nd	nd	nd	nd
PIAMH	1,040.55	73.9	299.14	21.2	68.98	4.9	1,408.67
MOBPH	4,866.13	75.6	1,366.39	21.2	205.02	3.2	6,437.53
YRKPH	940.91	83.3	157.29	13.9	32.39	2.8	1,130.59
YRKMH	96.47	99.6	0.21	0.2	0.17	0.2	96.47
MPNOH	nd	nd	nd	nd	nd	nd	nd
PMKOH	nd	nd	nd	nd	nd	nd	nd
MPNTF	nd	nd	nd	nd	nd	nd	nd
PMKTF	nd	nd	nd	nd	nd	nd	nd
JMSPH	261.6	84.0	43.6	14.0	3.9	1.0	309.1
Total Study Area	11,330.37		4,224.51		898.11		16,453.40

* nd = non-detectable SAV on photography

** = bay segment partially covered by this investigation

Potomac. The York and Piankatank regions that are located closer to the mouth of the bay (with potentially better water quality), including segments PIAMH, MOBPH, YRKMH, and YRKPH, had greater total SAV than the Rappahannock, but had proportionally less growing below 2m depths. In contrast to the relatively greater historical depth of SAV growth in the Rappahannock compared to the York, SAV abundance since 1971has been markedly less in the Rappahannock than the York and recent recoveries have been less (compare segments RPPMH, YRKMH and YRKPH, Appendix 1).

Comparisons of the historical (pre-1971) abundances of SAV to established goals for SAV restoration (Table 2) can provide insights into the potential for SAV recovery to the various tiered objective levels. For example the Tier 1 goal for bay segment CB6PH is approximately 512 ha., which is very close to the historical SAV abundance of 513 ha. The 1999 abundance was determined to be 268 ha. or about 50% of the historical abundance. These contrast to the much greater Tier 2 (1m) and Tier 3 (2m) depth-based goals of 1,230 and 3,249 ha. The current abundance of SAV would only be 22% and 8% respectively of these goals. Furthermore, although the additional bottom that has been projected for SAV growth deeper than 1m in segment CB6PH is about 164% of that area shallower than 1m (amount of Tier 3 area greater than Tier 2 compared to total Tier 2 area), the proportional area of SAV found to have been historically growing at depths deeper than 1m compared to shallower than 1m for this segment was only 25% (Table 1). This suggests that achieving growth to all areas with depths deeper than 1m in this bay segment will be difficult. Similar comparisons can be made for the other bay segments. These suggest, therefore, that realistic and achievable near-term SAV recovery goals should include some measures of historical growth and abundance.

The current (1999) abundances of SAV for the York and Rappahannock River study region are on average about 26% of the 1950s historical SAV abundances for this region (Table 2). Current

Table 2. Historical (Pre-1971), Tier 1, Tier 2, Tier 3, 1971-1999 Composite and Current (1999) Distribution of SAV by CBP Segment in Study Area.

BAY SEGMENT	HISTORICAL SAV (PRE 1971)	TIER 1	TIER 2	TIER 3	1971-1999 COMPOSITE	1999 TOTAL	1999 % HISTORICAL
CB6PH	512.82	511.84	1,593	2,076	669.17	267.59	52.18
CB5MH**	3,131.93	1,933.24	6,079	7,564	2,443.24	905.98	28.93
CRRMH	261.99	218.56	736	1,057	251.16	72.16	27.54
RPPMH	3,163.49	999.92	8,001	12,155	1051.05	33.12	1.05
RPPOH	nd	0	669	1,016	nd	0.0	-
RPPTF	nd	0	1,291	1,827	10.42	7.42	-
PIAMH	1,408.67	806.85	2,294	3,152	968.76	116.81	8.29
MOBPH	6,437.53	5,561.72	9,299	12,365	6,106.61	3,584.49	55.68
YRKPH	1,130.59	566.98	2,059	2,889	634.00	264.55	23.40
YRKMH	96.85	22.21	3,394	5,126	22.21	0.0	0.0
MPNOH	nd	0	180	248	nd	0.0	-
PMKOH	nd	0	242	348	nd	0.0	-
MPNTF	nd	0	403	547	34.38	0.0	-
PMKTF	nd	0	885	1,074	75.89	0.0	-
JMSPH	309.1	15.89	654	917	98.67	31.35	10.14
Total	16,453.40	10,637.21	37,779	52,361	12,365.56	5,283.47	Mean (25.90%)

* nd = nondetectable on photography

** = bay segment partially covered by this investigation

SAV abundances exceed 50% of historical abundance only in segments CB6PH and MOBPH that front along the lower Chesapeake Bay. The Rappahannock River (RPPMH) has demonstrated the greatest losses with only 1% of the 3,100 ha. of historical SAV still present. Similarly, the mesohaline portion of the York has experienced complete decline although only 100 ha. of SAV were found to have been growing in that region, historically.

No historical SAV was observed in low salinity and freshwater reaches of the Rappahannock River (RPPOH and RPPTF), nor the low salinity and freshwater reaches of the York system (YRKMH, MPNOH, MPNTF, PMKOH, PMKTF). Typically, SAV in these tidal areas are difficult to see due to the small areas of the beds and the usually high turbidity of the water. Tidal height is one of the most important constraints affecting the ability to discern SAV from aerial photography in these areas. Most SAV bed signatures are greatly obscured at mid to high tidal levels. Therefore it is not unusual that no SAV could be detected in these upstream areas, since the historical photography for these areas was not constrained as to conditions of tidal height, turbidity or season which are used as guidelines for current SAV photography missions (Orth et al. 2000). Recent aerial mapping combined with ground surveys beginning in the mid-1990s have delineated over 100 hectares of SAV in the Mattaponi and Pamunkey Rivers (Table 2; 1971-1999 Composite). Most are long, narrow beds located adjacent to the extensive tidal marsh and are difficult to delineate even using optimized photography. It is probable, however, that at least some of these beds were also present historically.

Historical Distribution as an Index of Water Quality Conditions

Strong positive relationships between water clarity and the maximum depth of growth of SAV have been demonstrated (Dennison et al. 1993: Duarte, 1991; Oleson 1996). Assuming a light requirement of approximately 22% of surface irradiance at the sediment surface necessary for long-term growth and survival of SAV in the polyhaline regions of the Chesapeake Bay (Batiuk et al. 2001), the presence of SAV to depths of 1.0 m or 1.5 m below mean low water (MLW) in this region would require light attenuation coefficients of approximately 1.0 m^{-1} or 0.7 m^{-1} respectively (with an average tidal range of 0.6m). These values are supported by similar median long-term light attenuation records of approximately 1.0 m^{-1} in the shallow littoral zone of the lower York River where SAV have been growing to 1 m MLW (this study; Moore et al. 1996).

Comparing present (1999) and historical maximum depths of SAV growth for various sites throughout the study area reveals that at many locations, the maximum depths of growth have decreased approximately 0.5 m. Using the 22% requirement for light availability through the water column (PLW), a decrease in maximum depth of growth from 1.8 m MSL (Mean Sea Level, assuming 0.6m tidal range) to 1.3 m MSL, would equate to a potential increase in water column light attenuation (K_d) from approximately 0.7 m^{-1} to 1.0 m^{-1} (or decrease in secchi of 2.0 m to 1.4 m). Similarly, a decrease in growth depth from 2.3 m MSL to 1.8 m MSL would equate to an increase in water column light attenuation from approximately 0.5 m^{-1} to 0.7 m^{-1} (or decrease in secchi of 2.9 m to 2.0 m). Historically, SAV in the tributaries appeared to grow to increasingly shallower depths with distance up river. For example, in the York River we found the historically maximum colonization depths varied from approximately 2.3 m MSL at the mouth, to 1.8 m MSL at the mid-range of the distribution, to 1.3 m MSL or less at the upper limits of growth approximately 26 km upriver. Growth to these depths would equate to an increase in light attenuation from 0.5 m^{-1} to 0.7 m^{-1} to 1.0 m^{-1} (or secchi decrease of 2.3 m to 2.0 m to 1.4 m). Shallow water monitoring of light attenuation at these three locations reveals median values of light attenuation measured bi-weekly from 1993 through 1998 of 1.0 m^{-1}, 1.3 m^{-1} and 1.8 m^{-1}, respectively (or secchi depths of 1.5 m, 1.1 m and 0.8 m).

Overall, the changes in SAV distributions reported here suggest a marked change in water clarity has occurred over the past 50 years. However, an undetermined decrease in light availability due to epiphytic fouling on the existing or potential new growth of SAV may also have been contributing to the change in growth depths. Typically, epiphytic fouling can account for 30% or greater of the total light reduction to the plants' leaves (PLL; Baliuk et al. 2001). This epiphyte accumulation is related to the complex interaction of a number of factors including water column nutrient levels, water clarity, suspended sediment concentrations and invertebrate grazer activity.

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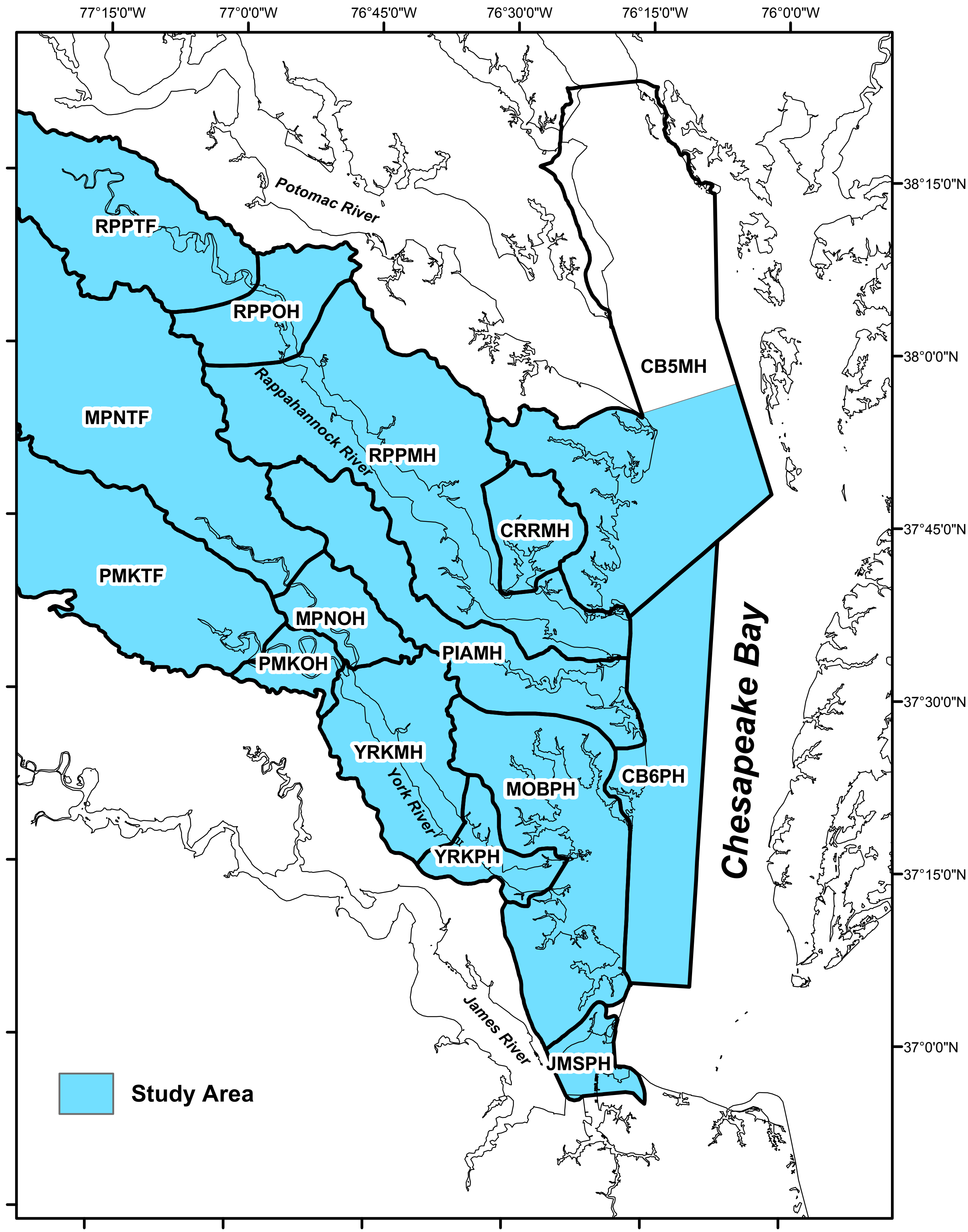
Appendix 1

CBP Bay Segments Showing Distribution and Abundance of Historical SAV



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76°0'0"W
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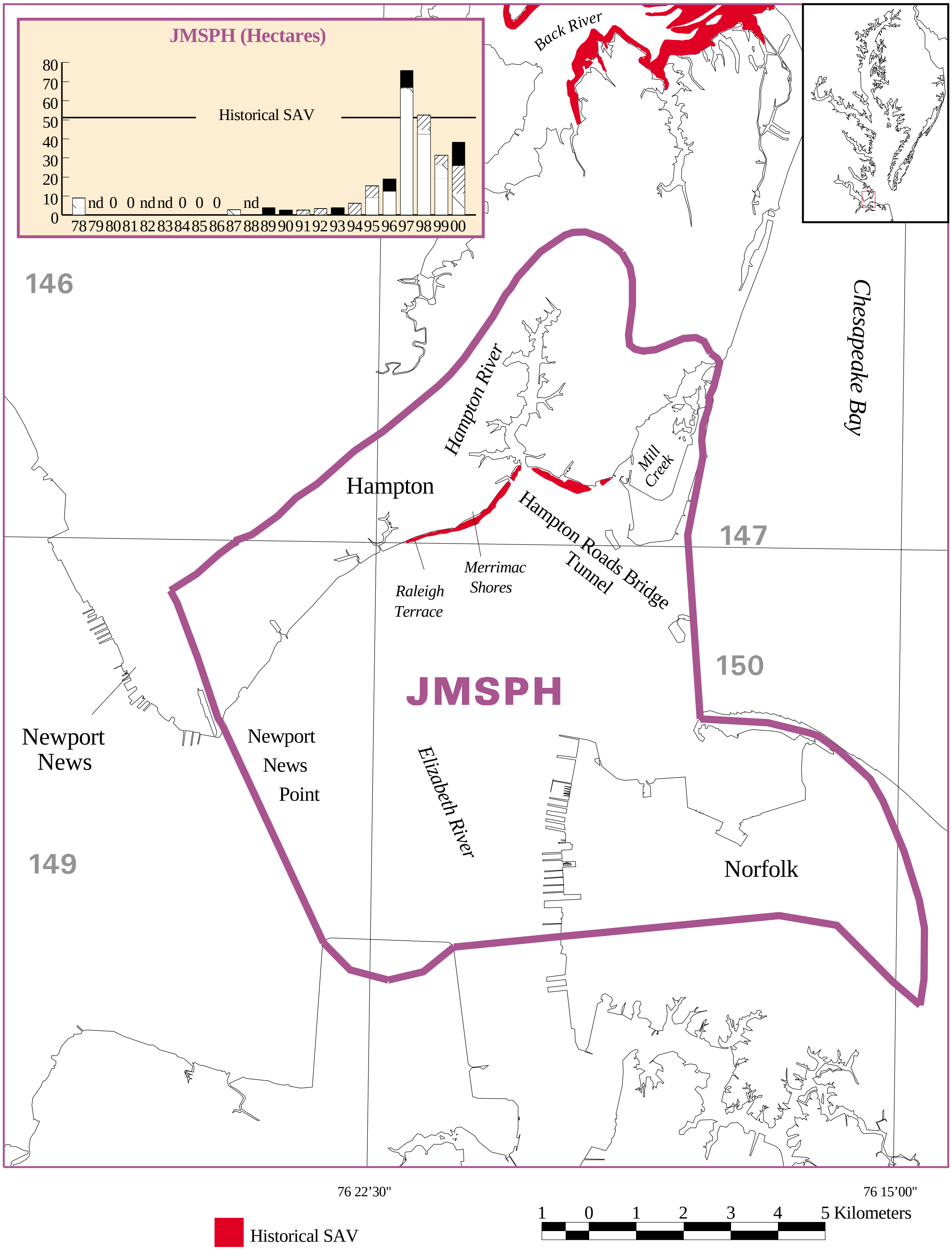
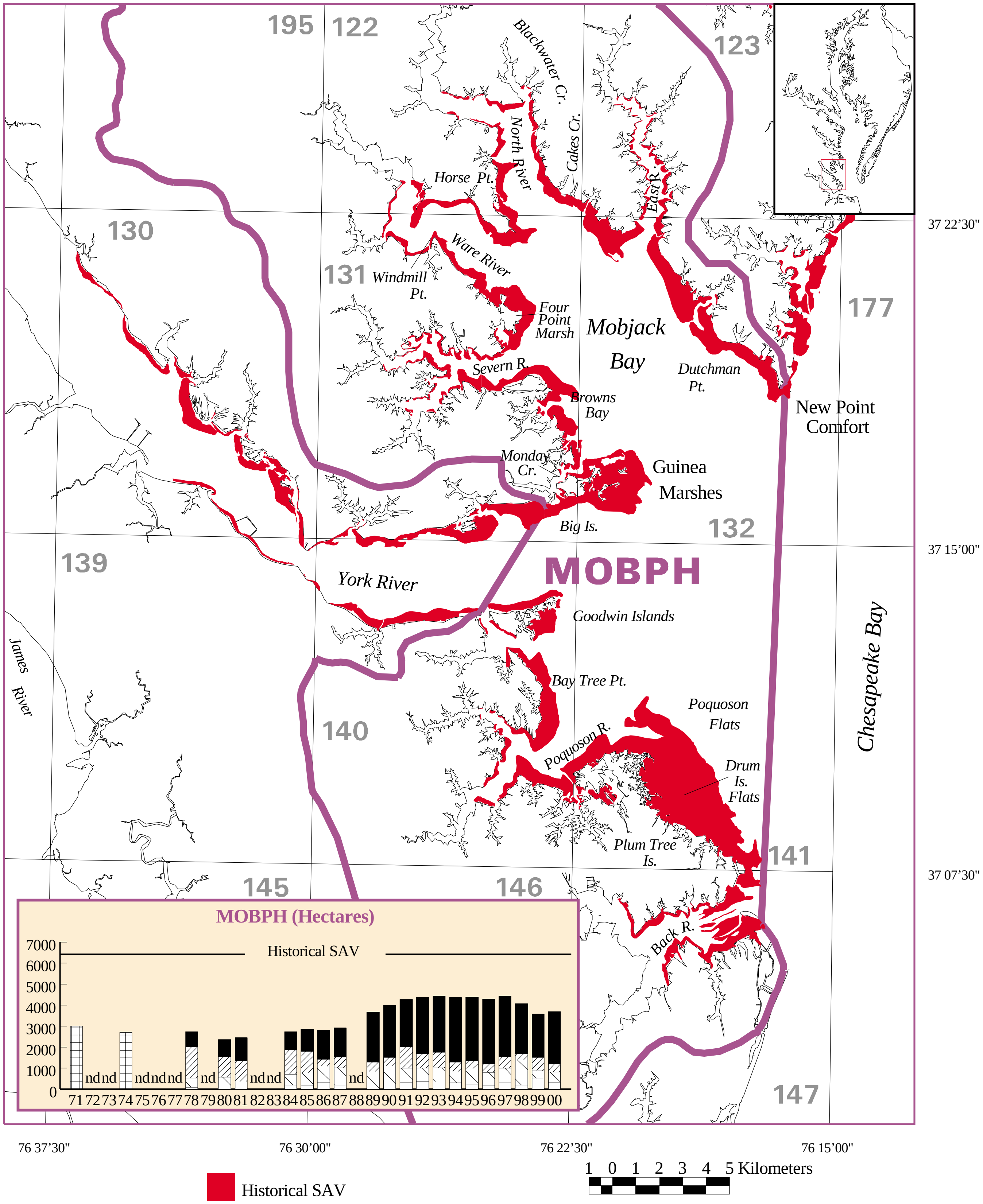
38°0'0"N
37°45'0"N
37°30'0"N
37°15'0"N
37°0'0"N
Potomac River
Rappahannock River
York River
James River
Chesapeake Bay
RPPTF
RPPOH
RPPMH
MPNTF
PMKTF
MPNOH
PMKOH
PIAMH
CRRMH
CB5MH
CB6PH
YRKMH
YRKPH
MOBPH
JMSPH
Study Area



JMSPH (Hectares)
80
70
60
50
40
30
20
10
0
Historical SAV
nd 0 0 nd nd 0 0 0 nd
78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00
Back River
146
Chesapeake Bay
Hampton River
Mill Creek
Hampton
147
37 00'00"
Hampton Roads Bridge Tunnel
Merrimac Shores
Raleigh Terrace
150
JMSPH
Newport News
Newport News Point
Elizabeth River
149
Norfolk
76 22'30"
76 15'00"
1 0 1 2 3 4 5 Kilometers
Historical SAV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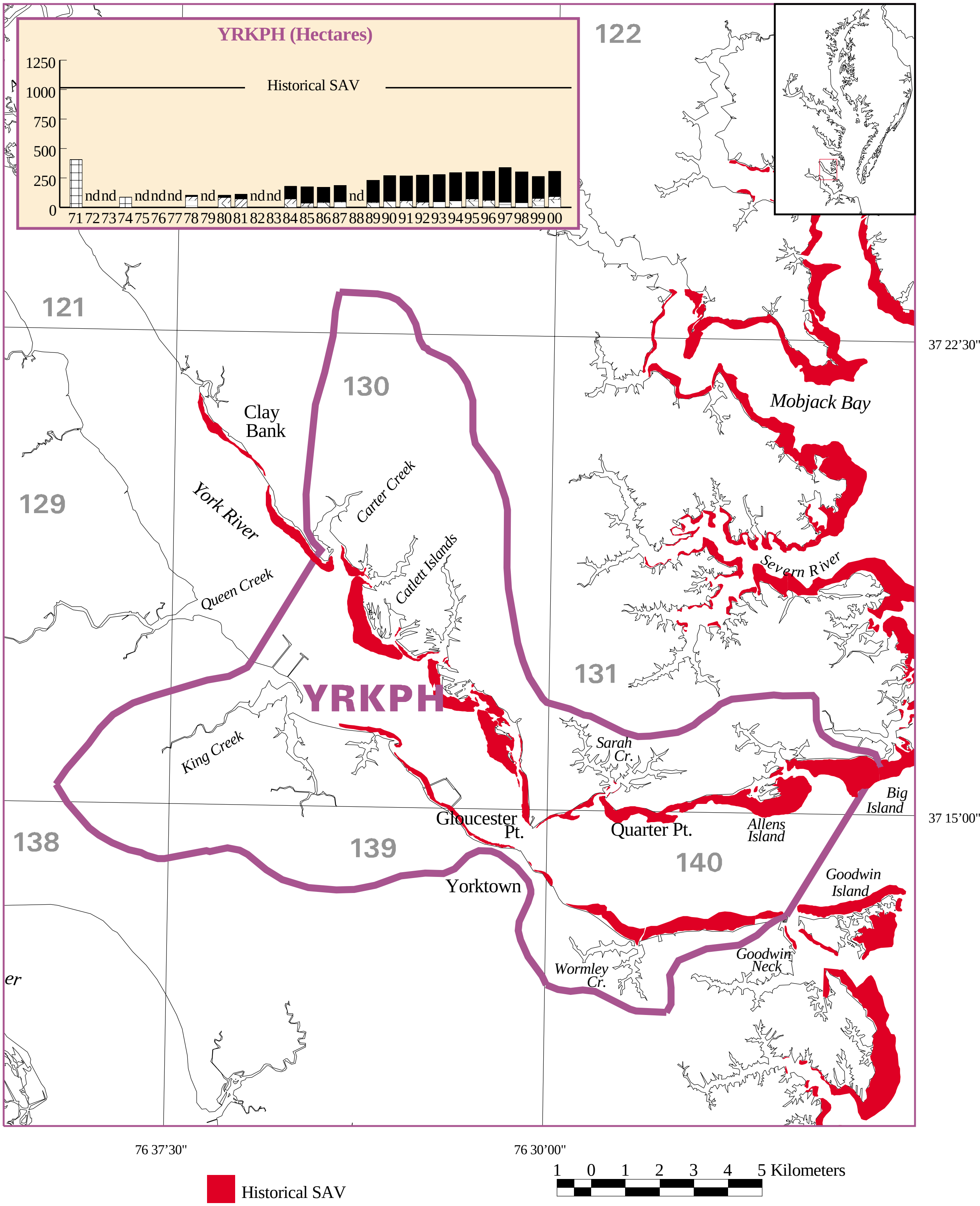
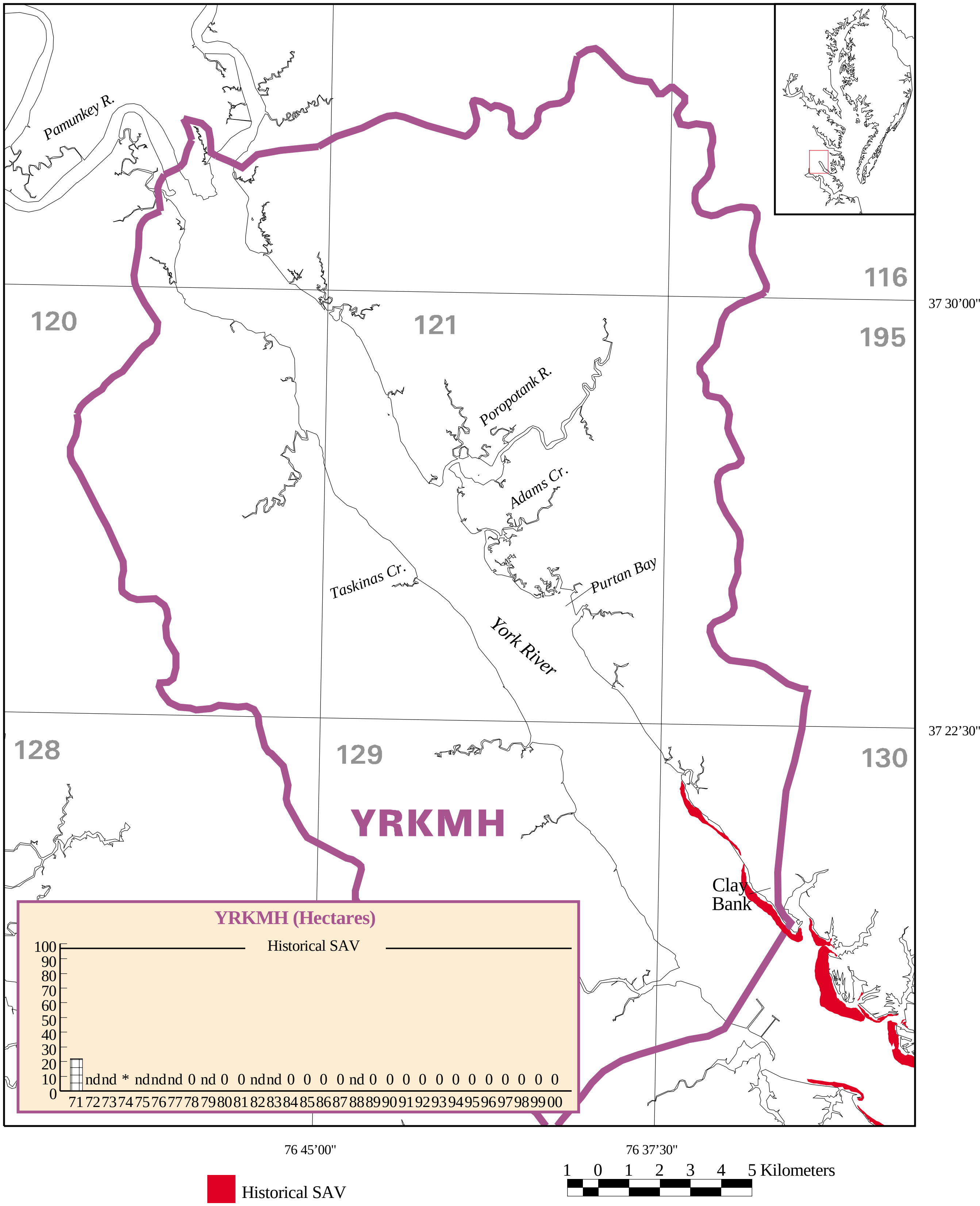
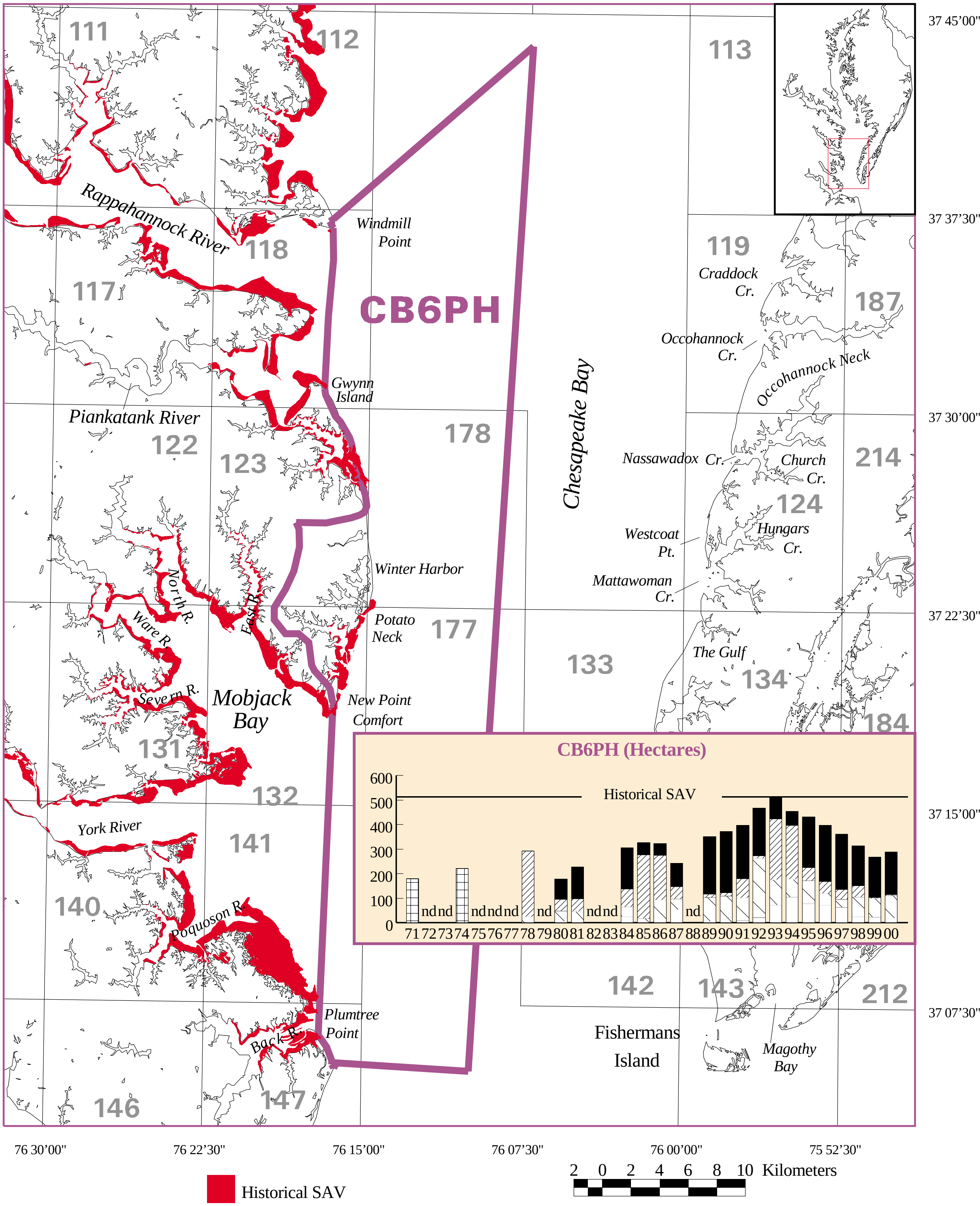
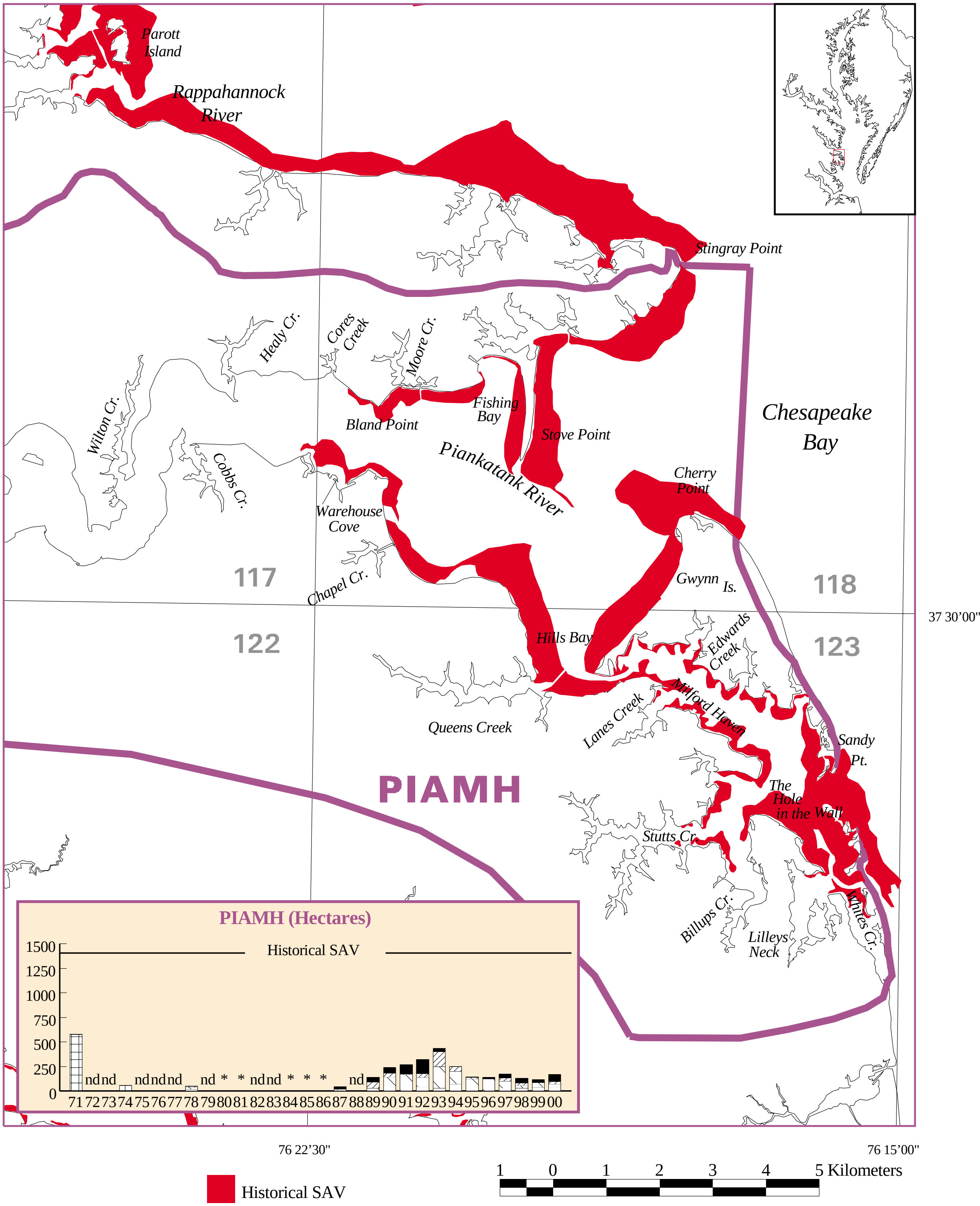
122
123
Blackwater Cr.
North River
Cakes Cr.
East R.
Horse Pt.
130
131
Windmill Pt.
Ware River
Four Point Marsh
Mobjack Bay
Dutchman Pt.
177
New Point Comfort
Severn R.
Browns Bay
Monday Cr.
Guinea Marshes
Big Is.
132
139
MOBPH
York River
Goodwin Islands
James River
Bay Tree Pt.
Poquoson Flats
Chesapeake Bay
140
Poquoson R.
Drum Is. Flats
Plum Tree Is.
141
145
146
Back R.
147
37 22'30"
37 15'00"
37 07'30"
76 37'30"
76 30'00"
76 22'30"
76 15'00"
MOBPH (Hectares)
Historical SAV
7000
6000
5000
4000
3000
2000
1000
0
nd nd nd nd nd nd nd nd nd
71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00
Historical SAV
1 0 1 2 3 4 5 Kilometers

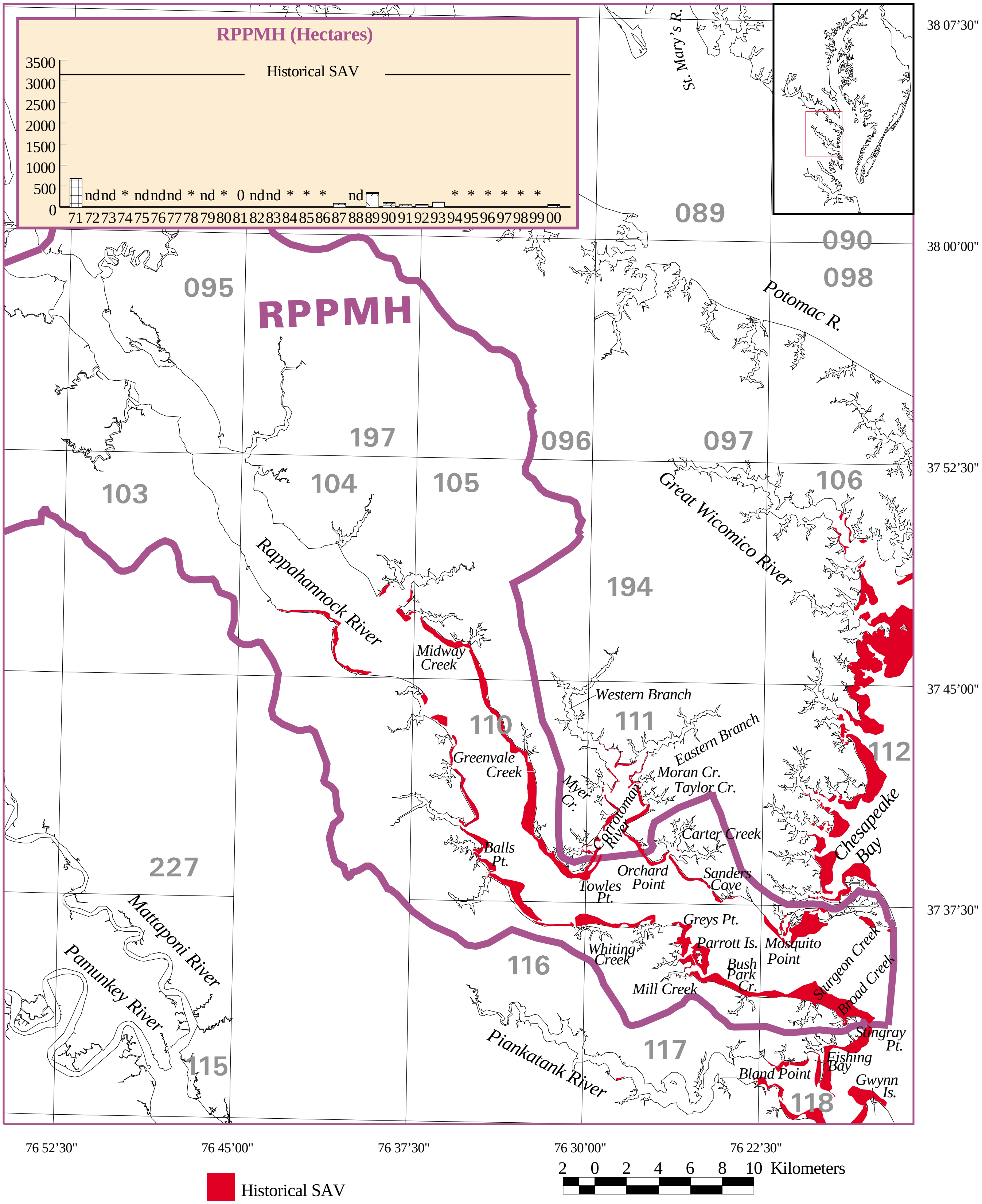

YRKPH (Hectares)
Historical SAV
1250
1000
750
500
250
0
71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00
nd nd
nd nd nd
nd
nd nd
nd
122
121
130
129
131
138
139
140
YRKPH
Clay Bank
York River
Carter Creek
Catlett Islands
Queen Creek
King Creek
Mobjack Bay
Severn River
Sarah Cr.
Gloucester Pt.
Quarter Pt.
Allens Island
Big Island
Yorktown
Goodwin Island
Goodwin Neck
Wormley Cr.
37 22'30"
37 15'00"
76 37'30"
76 30'00"
1 0 1 2 3 4 5 Kilometers
Historical SAV

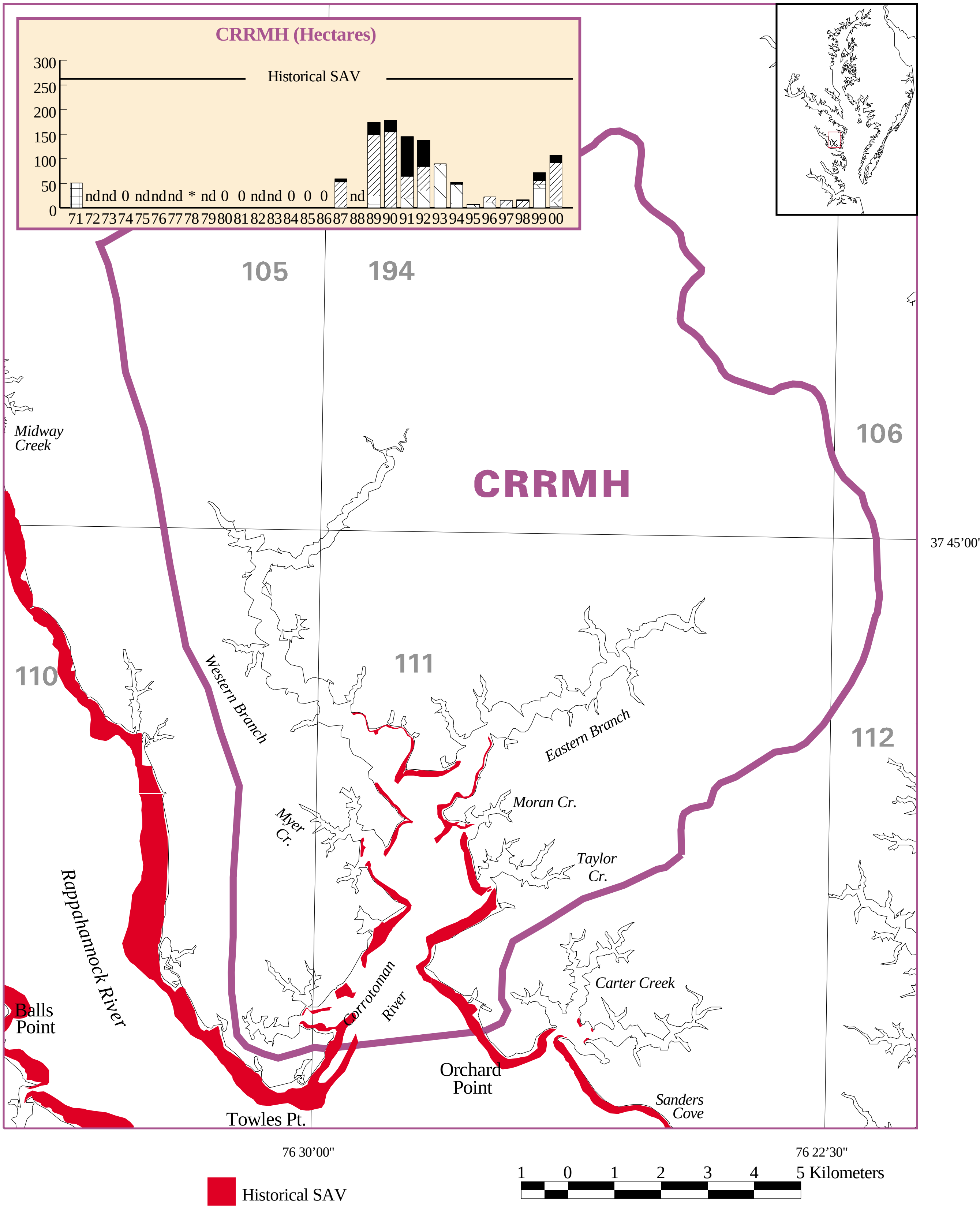

Pamunkey R.
120
121
116
195
37 30'00"
Poropotank R.
Adams Cr.
Taskinas Cr.
Purtan Bay
York River
128
129
130
37 22'30"
YRKMH
Clay
Bank
YRKMH (Hectares)
Historical SAV
100
90
80
70
60
50
40
30
20
10
0
nd nd * nd nd nd 0 nd 0 0 nd nd 0 0 0 0 nd 0 0 0 0 0 0 0 0 0 0 0 0
71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00
76 45'00"
76 37'30"
1 0 1 2 3 4 5 Kilometers
Historical SAV

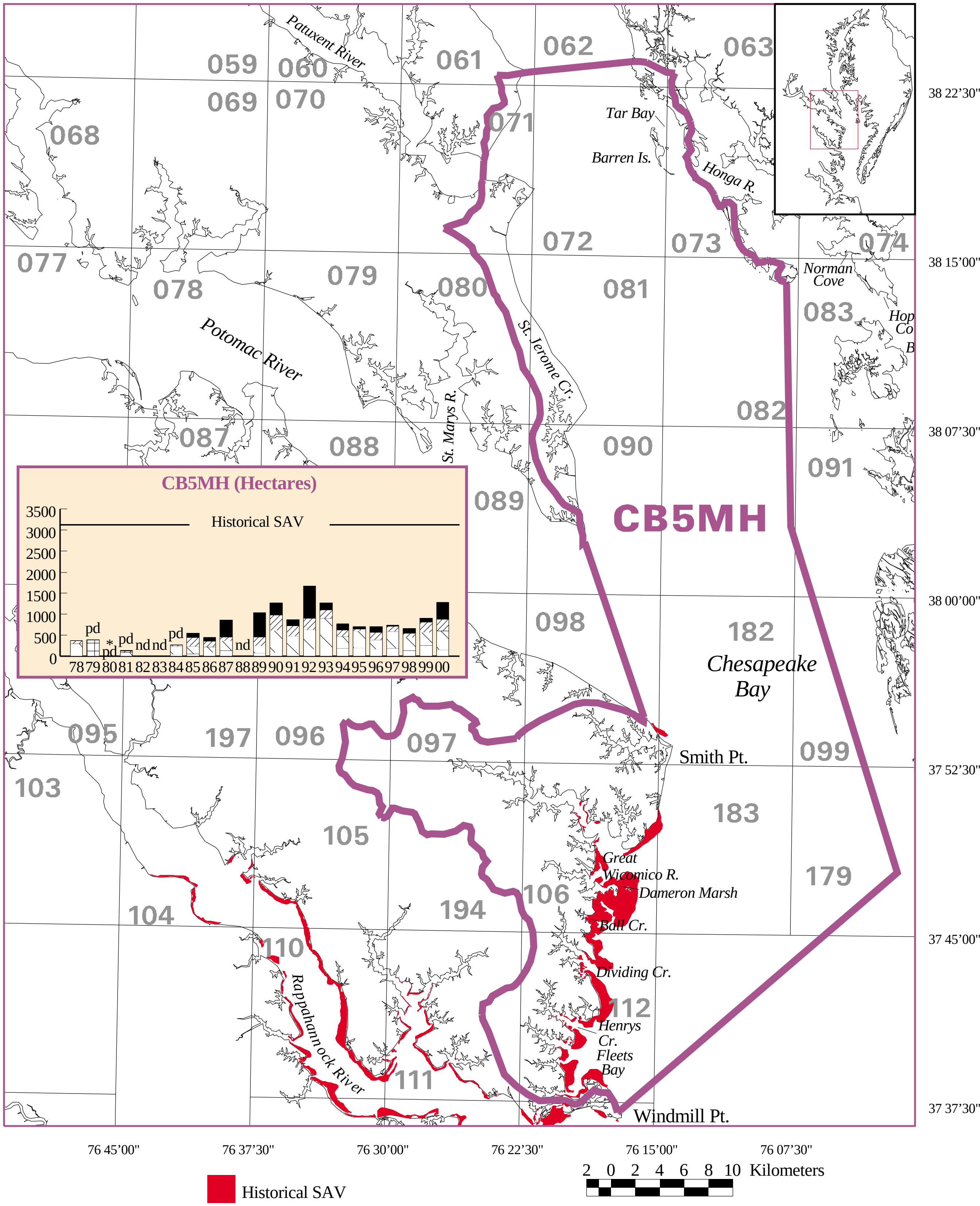


CB6PH
111
112
113
117
118
119
122
123
124
131
132
133
134
140
141
142
143
146
147
177
178
184
187
212
214
Rappahannock River
Windmill Point
Piankatank River
Gwynn Island
Winter Harbor
Potato Neck
New Point Comfort
North R.
East R.
Ware R.
Severn R.
Mobjack Bay
York River
Poquoson R.
Plumtree Point
Back R.
Chesapeake Bay
Craddock Cr.
Occohannock Cr.
Occohannock Neck
Nassawadox Cr.
Church Cr.
Westcoat Pt.
Hungars Cr.
Mattawoman Cr.
The Gulf
Fishermans Island
Magothy Bay
37 45'00"
37 37'30"
37 30'00"
37 22'30"
37 15'00"
37 07'30"
76 30'00"
76 22'30"
76 15'00"
76 07'30"
76 00'00"
75 52'30"
CB6PH (Hectares)
Historical SAV
600
500
400
300
200
100
0
nd
71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00
2 0 2 4 6 8 10 Kilometers
Historical SAV


Parott Island
Rappahannock River
Stingray Point
Chesapeake Bay
Healy Cr.
Cores Creek
Moore Cr.
Wilton Cr.
Cobbs Cr.
Fishing Bay
Bland Point
Stove Point
Piankatank River
Cherry Point
Warehouse Cove
Chapel Cr.
Gwynn Is.
Hills Bay
Edwards Creek
Milford Haven
Lanes Creek
Queens Creek
Sandy Pt.
The Hole in the Wall
Stutts Cr.
Billups Cr.
Lilleys Neck
Whites Cr.
117
118
122
123
37 30'00"
PIAMH
PIAMH (Hectares)
Historical SAV
1500
1250
1000
750
500
250
0
nd nd nd nd nd nd * * nd nd * * * nd
71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00
76 22'30"
76 15'00"
1 0 1 2 3 4 5 Kilometers
Historical SAV


RPPMH (Hectares)
Historical SAV
3500
3000
2500
2000
1500
1000
500
0
nd nd * nd nd nd * nd * 0 nd nd * * * nd * * * * * *
71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00
RPPMH
St. Mary's R.
Potomac R.
Great Wicomico River
Rappahannock River
Midway Creek
Western Branch
Eastern Branch
Moran Cr.
Taylor Cr.
Myer Cr.
Corrotoman River
Greenvale Creek
Carter Creek
Balls Pt.
Orchard Point
Sanders Cove
Towles Pt.
Chesapeake Bay
Greys Pt.
Parrott Is.
Mosquito Point
Whiting Creek
Bush Park Cr.
Mill Creek
Sturgeon Creek
Broad Creek
Stingray Pt.
Fishing Bay
Bland Point
Gwynn Is.
Piankatank River
Mattaponi River
Pamunkey River
089
090
098
095
197
096
097
103
104
105
106
194
110
111
112
227
116
117
115
118
38 07'30"
38 00'00"
37 52'30"
37 45'00"
37 37'30"
76 52'30"
76 45'00"
76 37'30"
76 30'00"
76 22'30"
2 0 2 4 6 8 10 Kilometers
Historical SAV

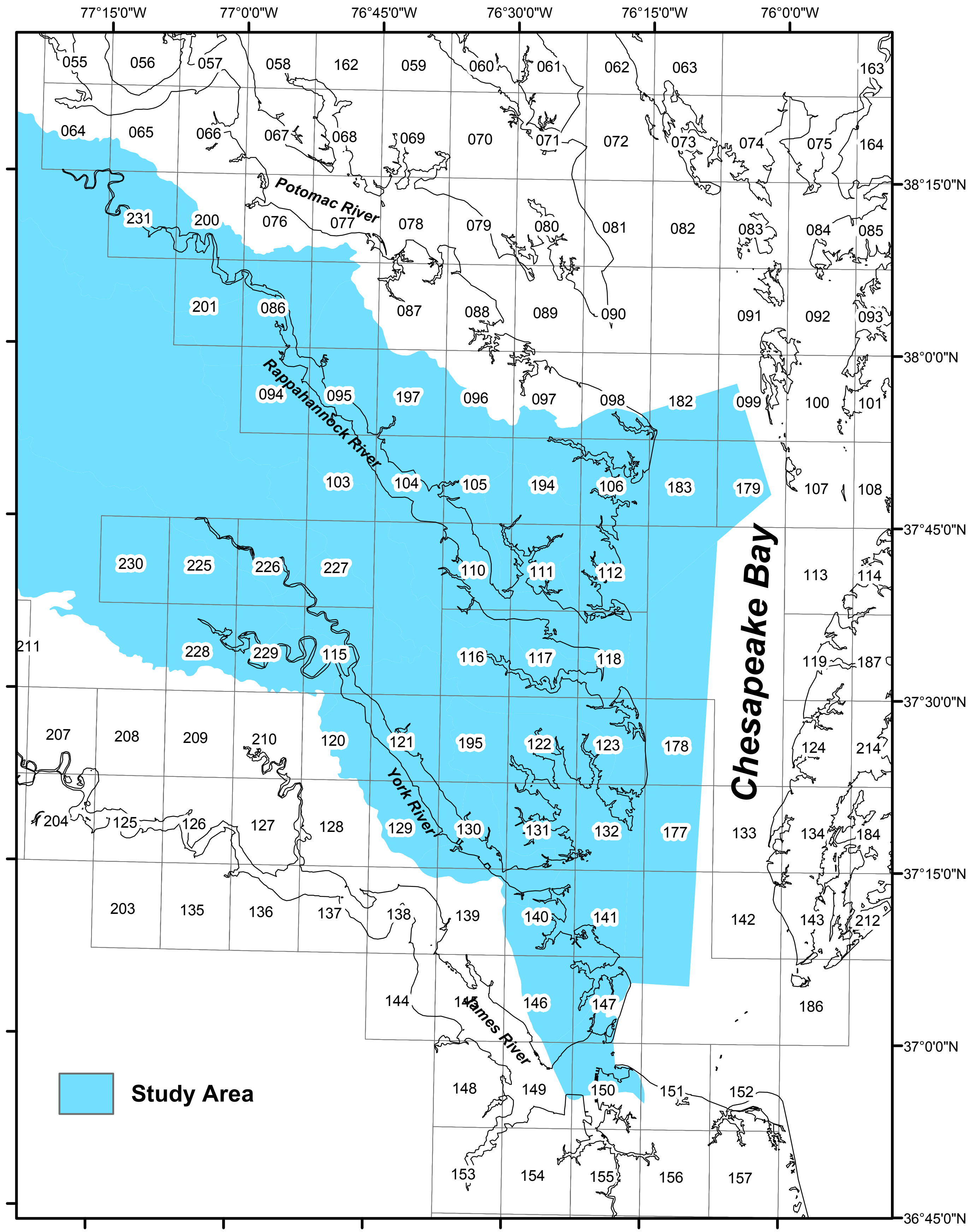

CRRMH (Hectares)
300
250
200
150
100
50
0
Historical SAV
nd nd 0 nd nd nd * nd 0 0 nd nd 0 0 0 nd
71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00
105
194
106
CRRMH
37 45'00"
Midway Creek
110
111
112
Western Branch
Eastern Branch
Moran Cr.
Myer Cr.
Taylor Cr.
Rappahannock River
Corrotoman River
Carter Creek
Balls Point
Orchard Point
Towles Pt.
Sanders Cove
76 30'00"
76 22'30"
1 0 1 2 3 4 5 Kilometers
Historical SAV


CB5MH
CB5MH (Hectares)
Historical SAV
3500
3000
2500
2000
1500
1000
500
0
pd
pd
*
pd
nd
nd
pd
nd
78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00
Patuxent River
Tar Bay
Barren Is.
Honga R.
Norman Cove
Potomac River
St. Jerome Cr.
St. Marys R.
Chesapeake Bay
Smith Pt.
Great Wicomico R.
Dameron Marsh
Ball Cr.
Dividing Cr.
Henrys Cr.
Fleets Bay
Windmill Pt.
Rappahannock River
059
060
061
062
063
068
069
070
071
072
073
074
077
078
079
080
081
082
083
087
088
089
090
091
095
096
097
098
099
103
104
105
106
110
111
112
179
182
183
194
197
38 22'30"
38 15'00"
38 07'30"
38 00'00"
37 52'30"
37 45'00"
37 37'30"
76 45'00"
76 37'30"
76 30'00"
76 22'30"
76 15'00"
76 07'30"
2 0 2 4 6 8 10 Kilometers
Historical SAV

Appendix 2

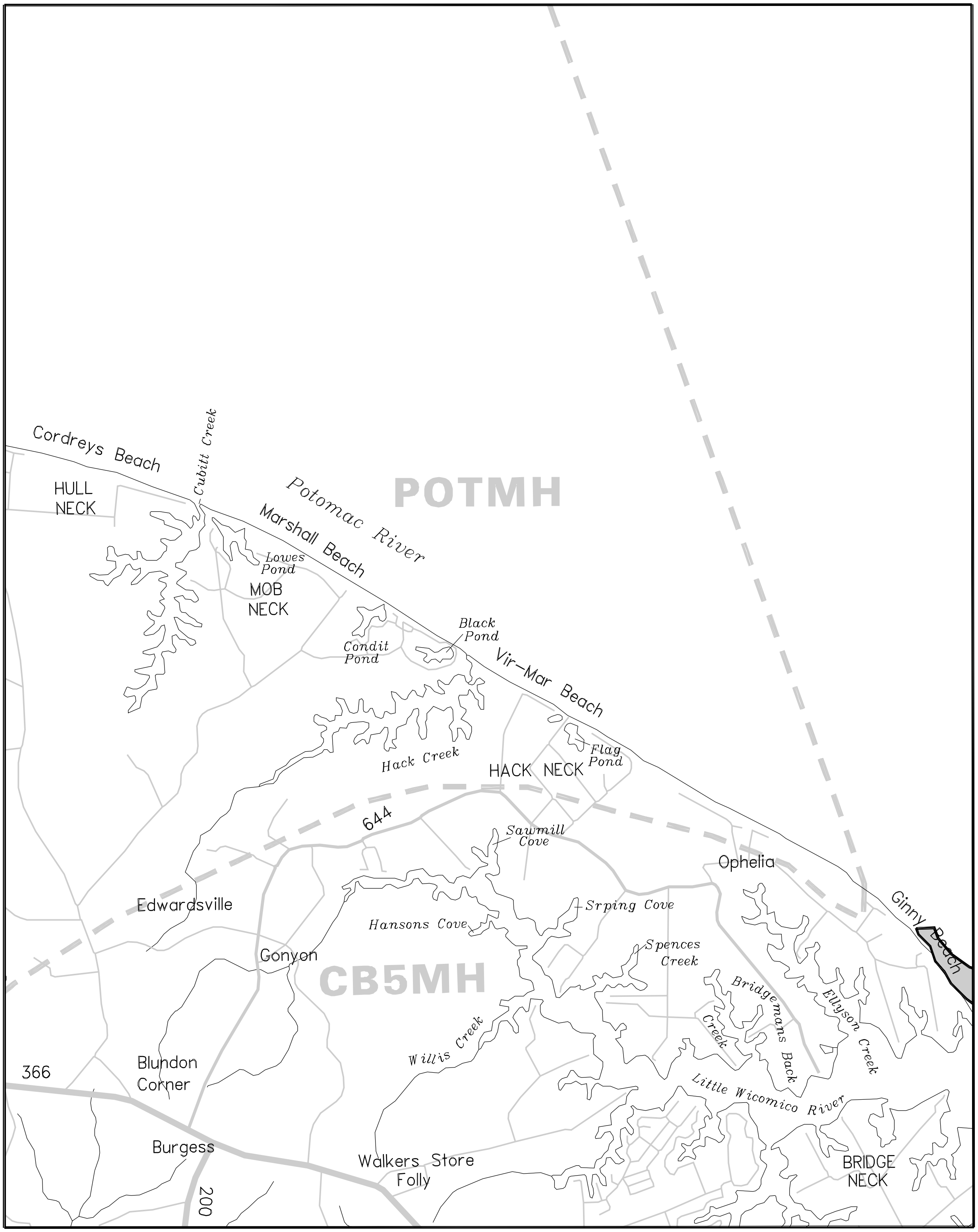
7.5 minute USGS Quadrangles Showing Distribution and Abundance

Of Historical SAV


77°15'0"W
77°0'0"W
76°45'0"W
76°30'0"W
76°15'0"W
76°0'0"W
38°15'0"N
38°0'0"N
37°45'0"N
37°30'0"N
37°15'0"N
37°0'0"N
36°45'0"N
Potomac River
Rappahannock River
York River
James River
Chesapeake Bay
Study Area

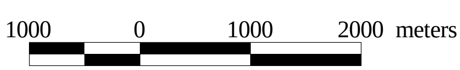
Historical Submerged Aquatic Vegetation

Burgess, Va.- Md. (098)



Hectares of SAV: 18.50

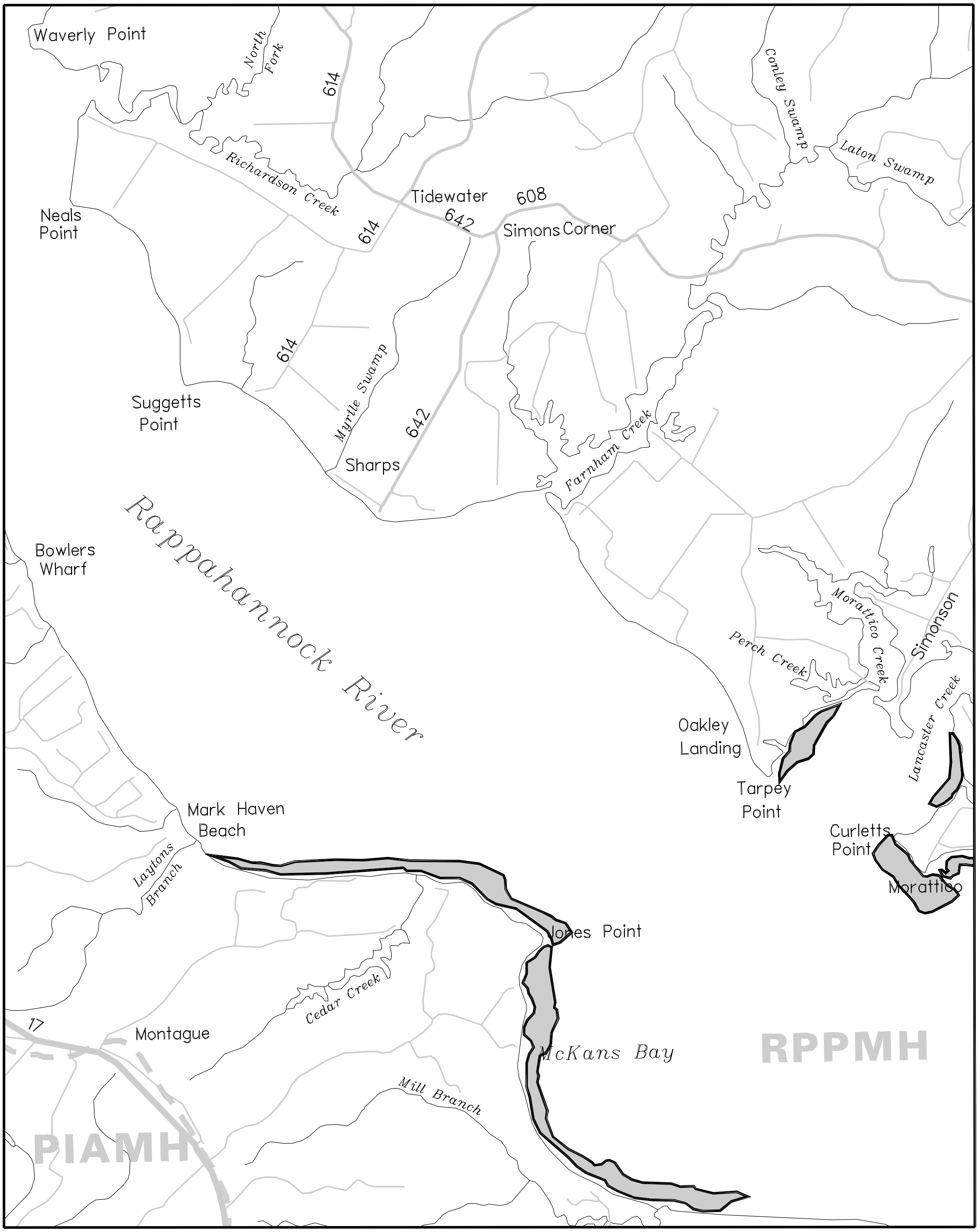
Historical SAV Coverage



Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Morattico, Va. (104)



Hectares of SAV: 211.27

1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Lively, Va. (105)

Hectares of SAV: 173.22

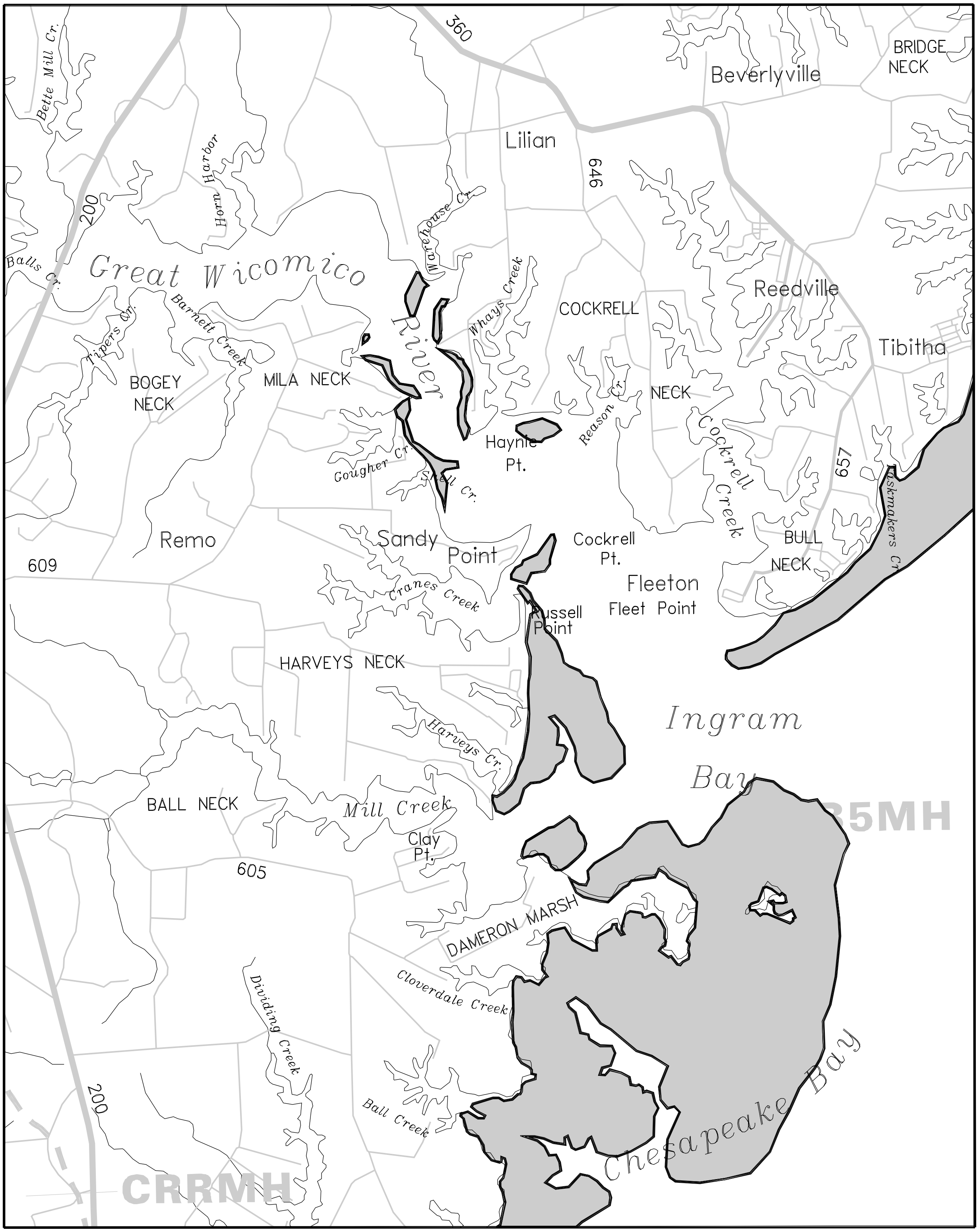
1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Reedville, Va. (106)



Hectares of SAV: 1,611.91

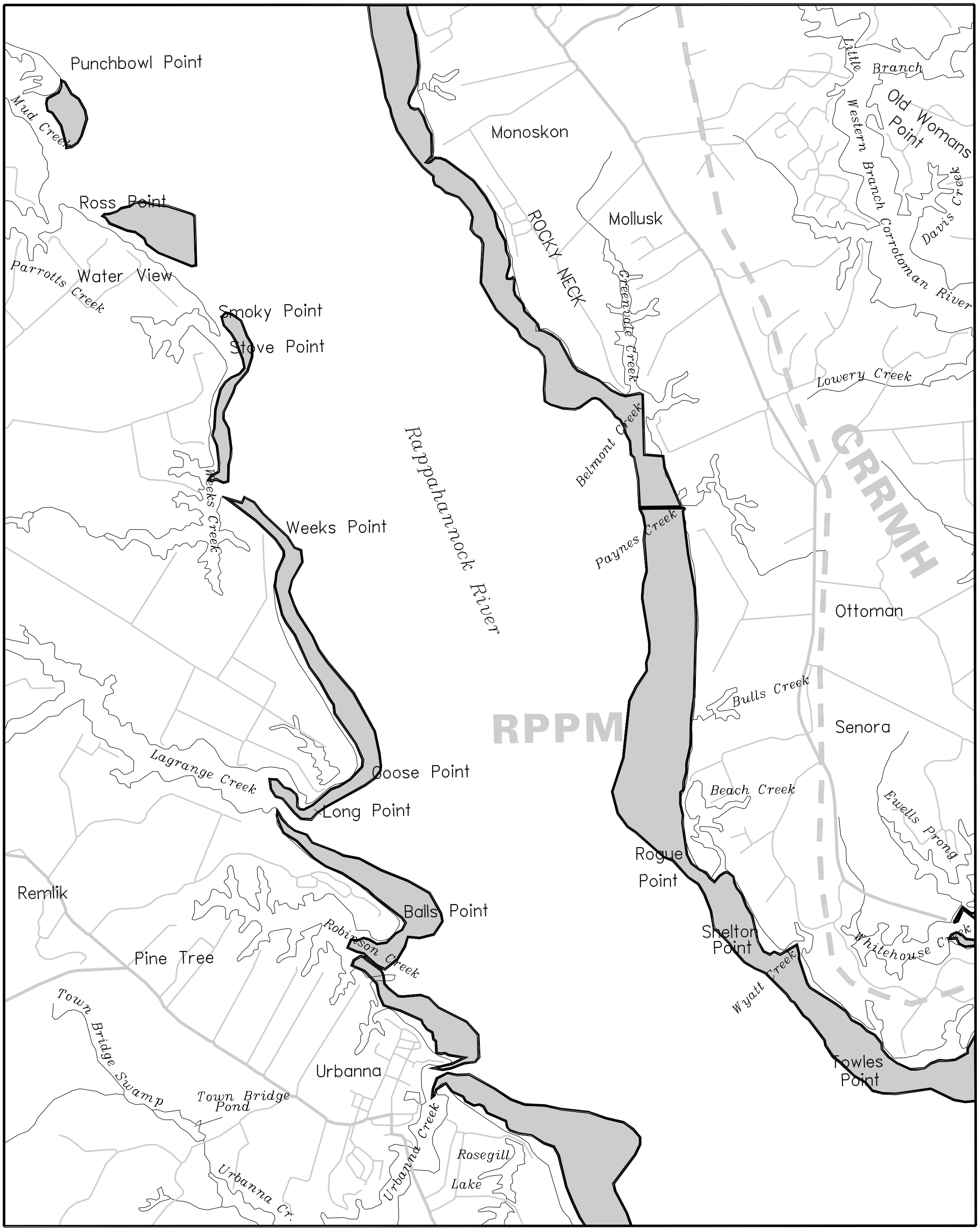
1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Urbanna, Va. (110)



Hectares of SAV: 1,033.96

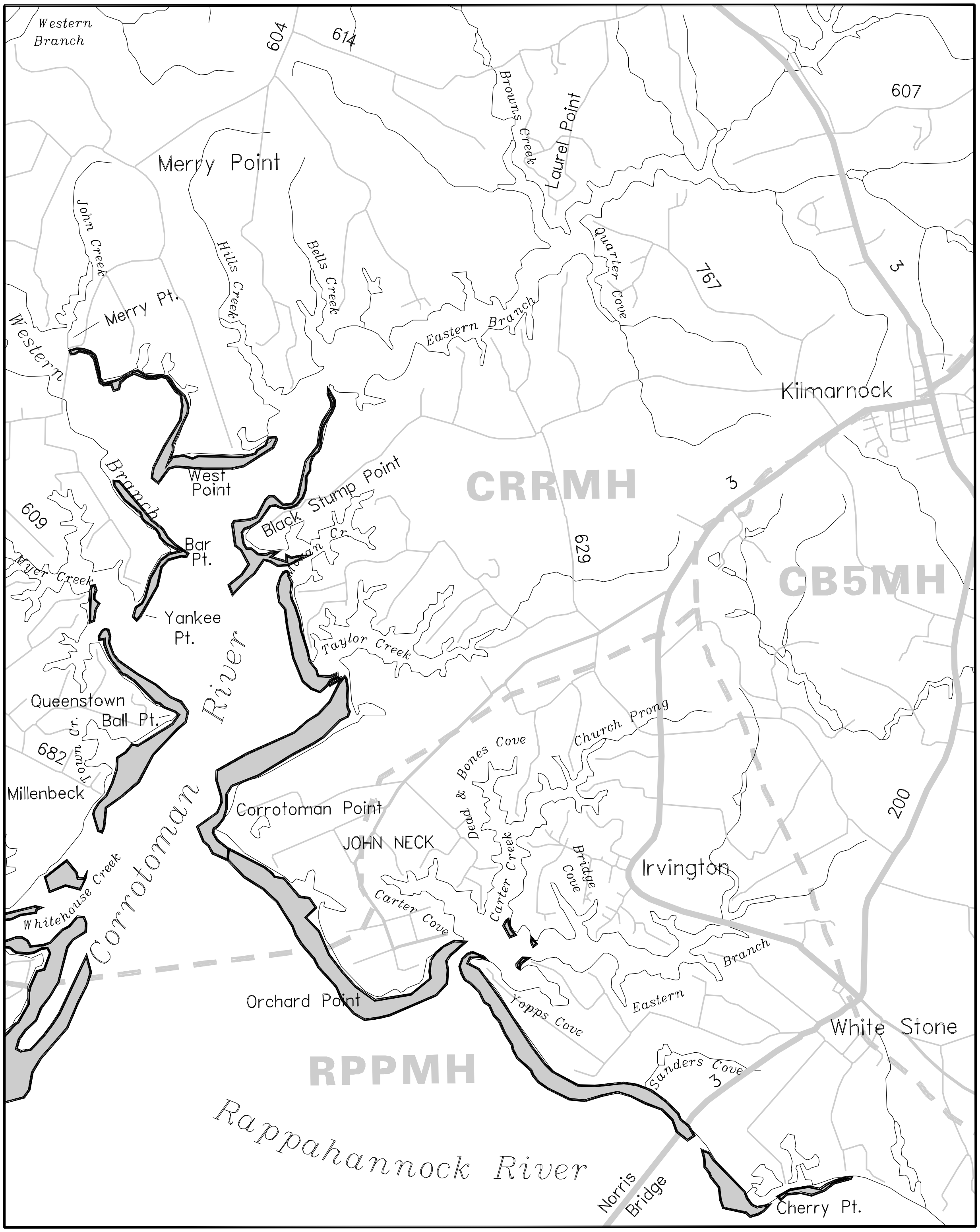
1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Irvington, Va. (111)



Hectares of SAV: 424.49

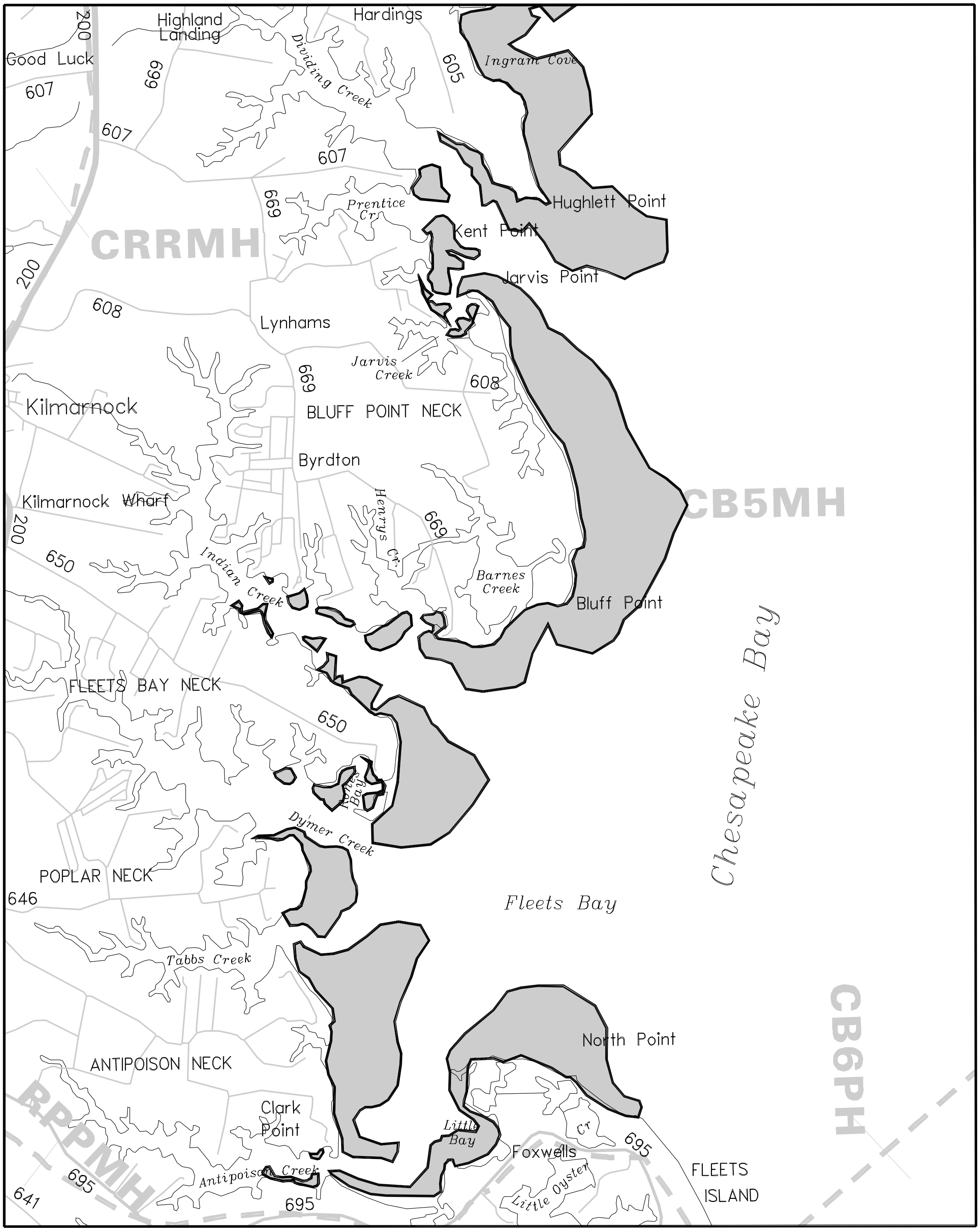
1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Fleets Bay, Va. (112)



Hectares of SAV: 1,417.70

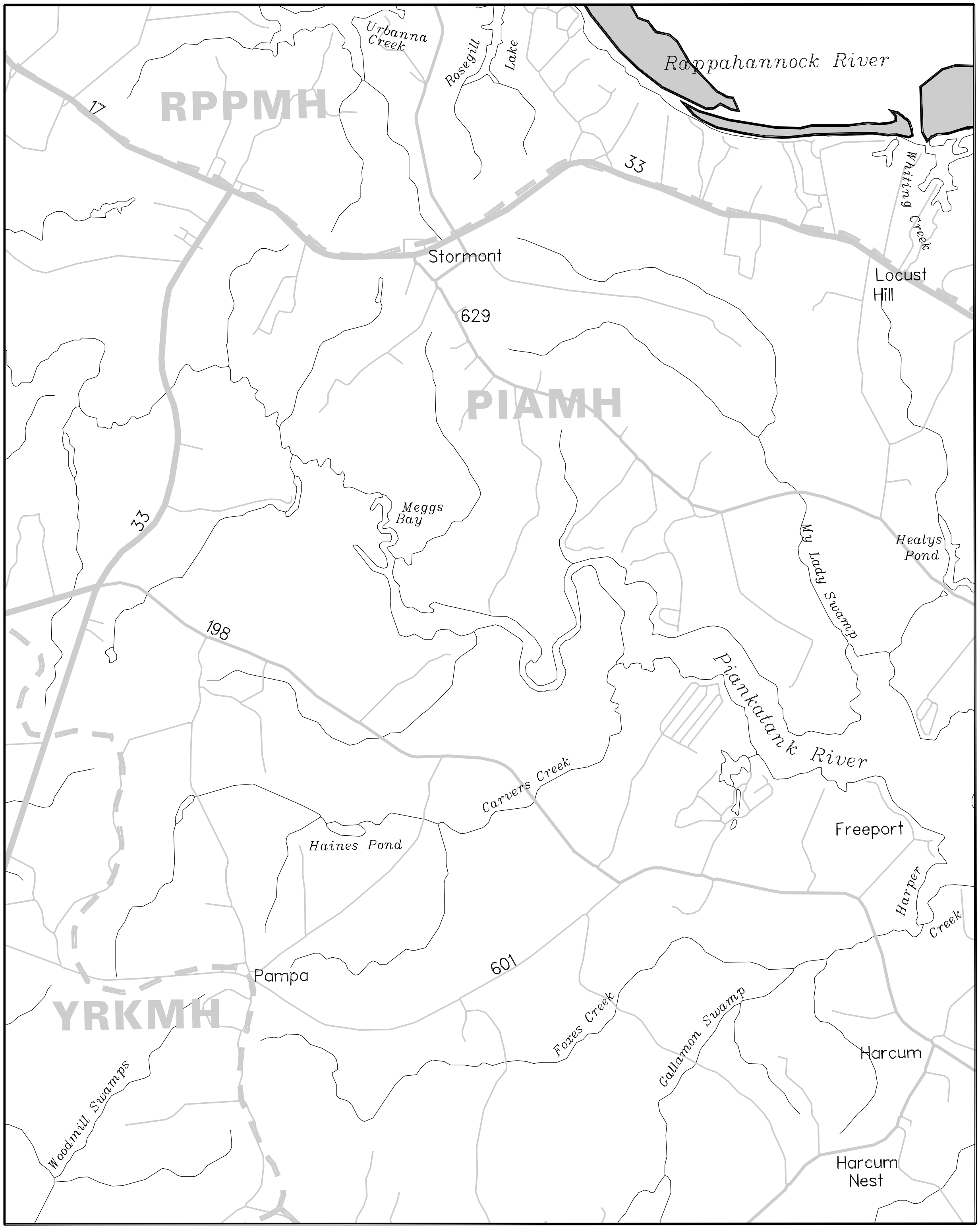
1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Saluda, Va. (116)



Hectares of SAV: 142.33

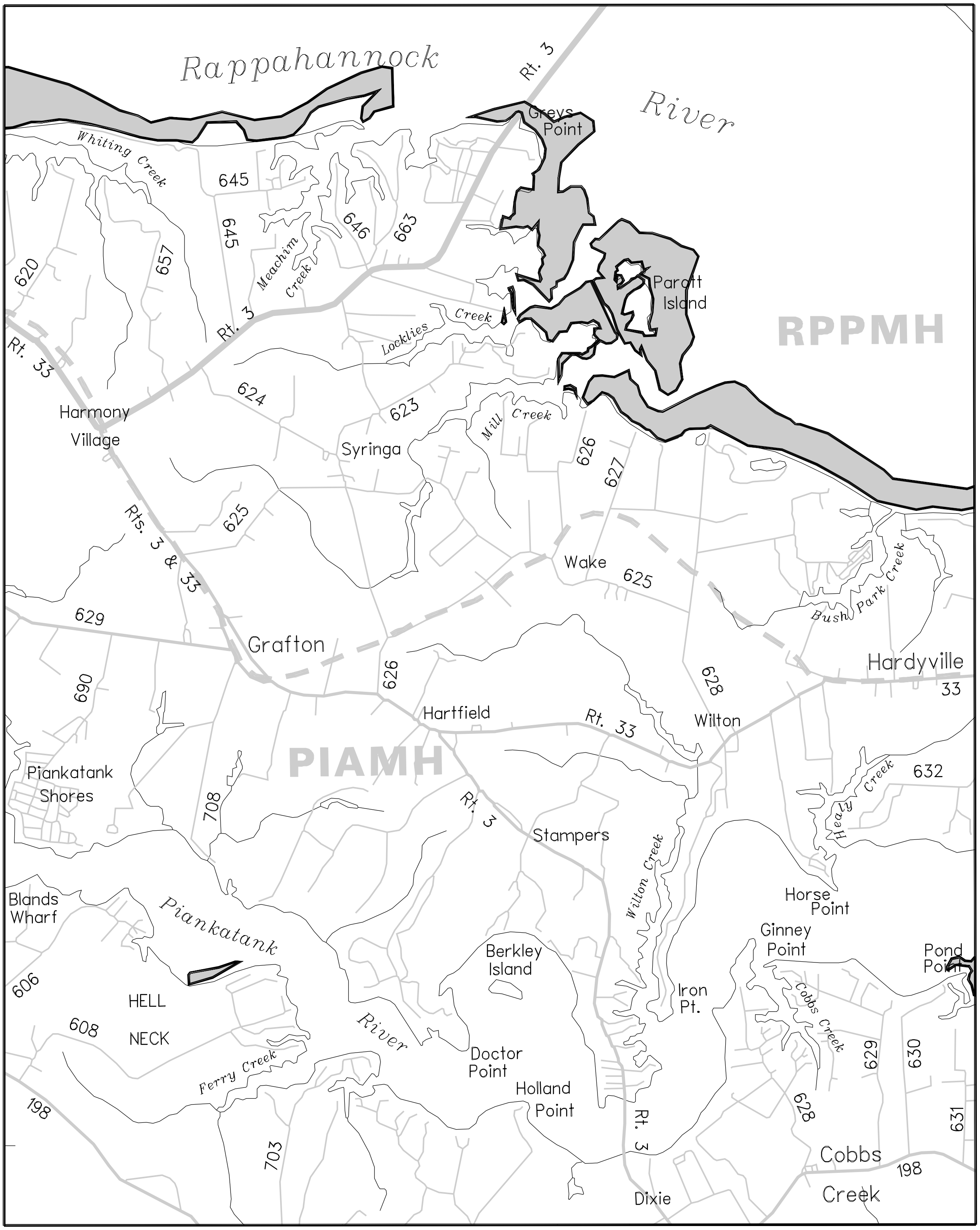
1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Wilton, Va. (117)



Hectares of SAV: 576.12

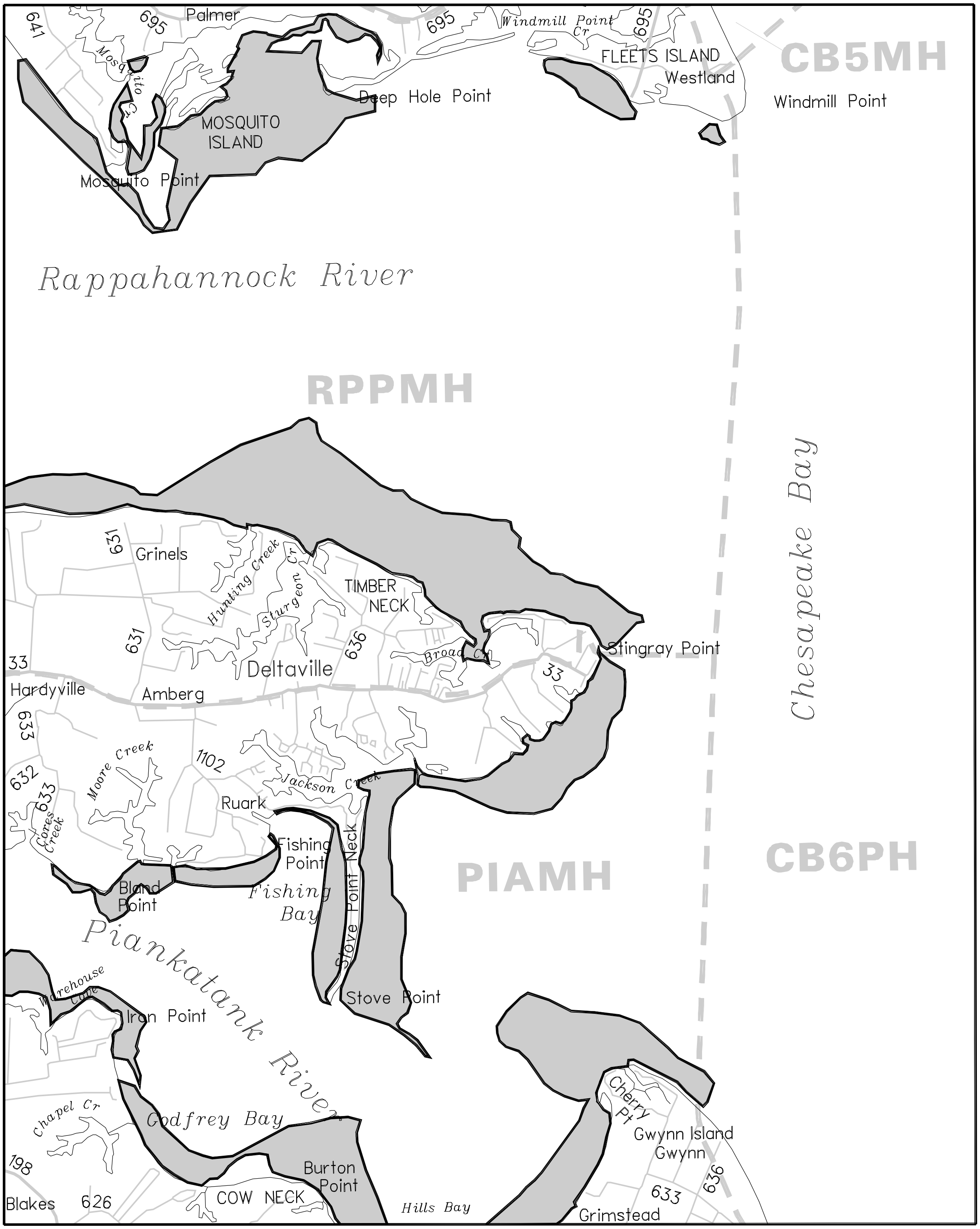
Historical SAV Coverage

1000 0 1000 2000 meters

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Deltaville, Va. (118)



Hectares of SAV: 1,680.10

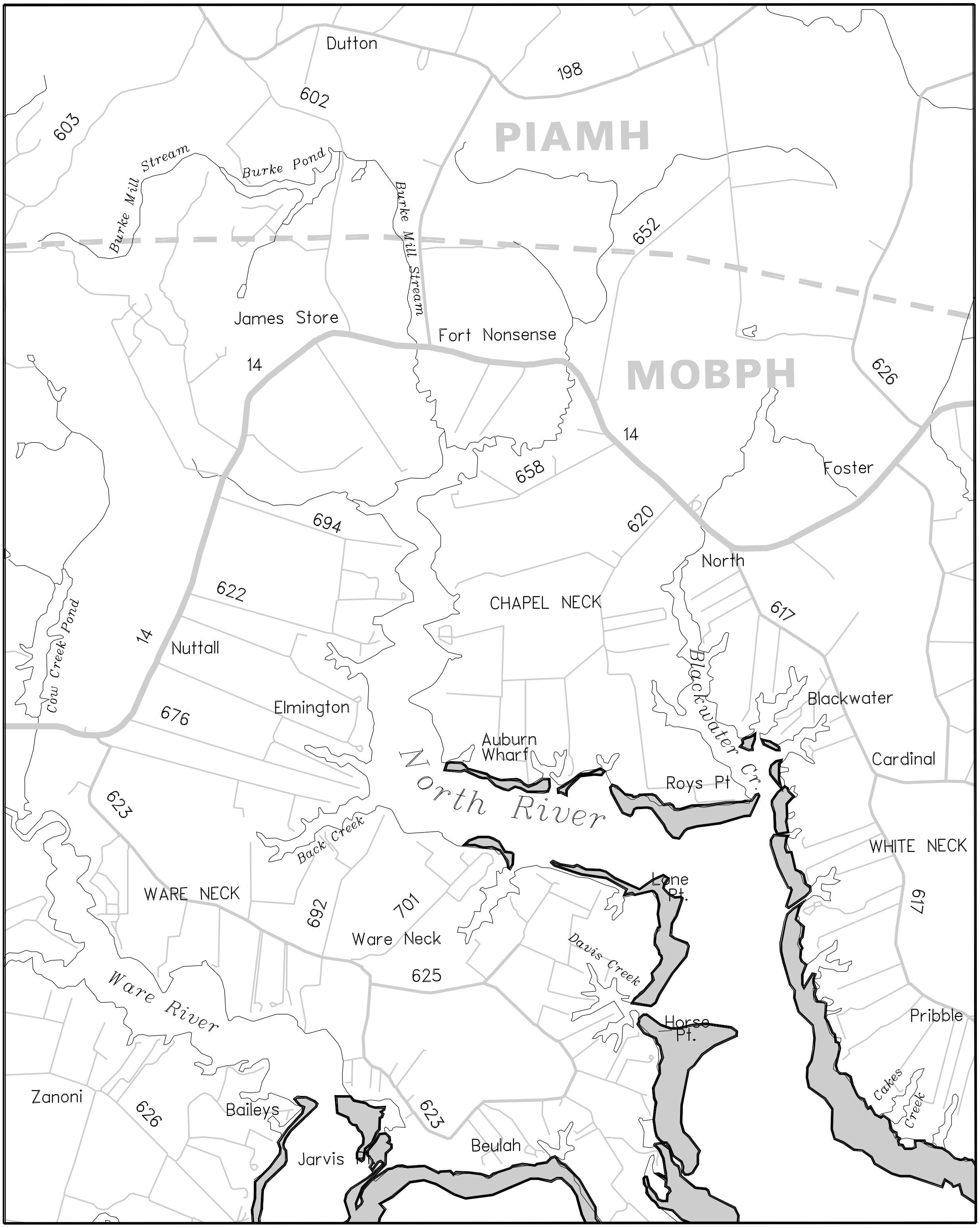
1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Ware Neck, Va. (122)



Hectares of SAV: 472.40

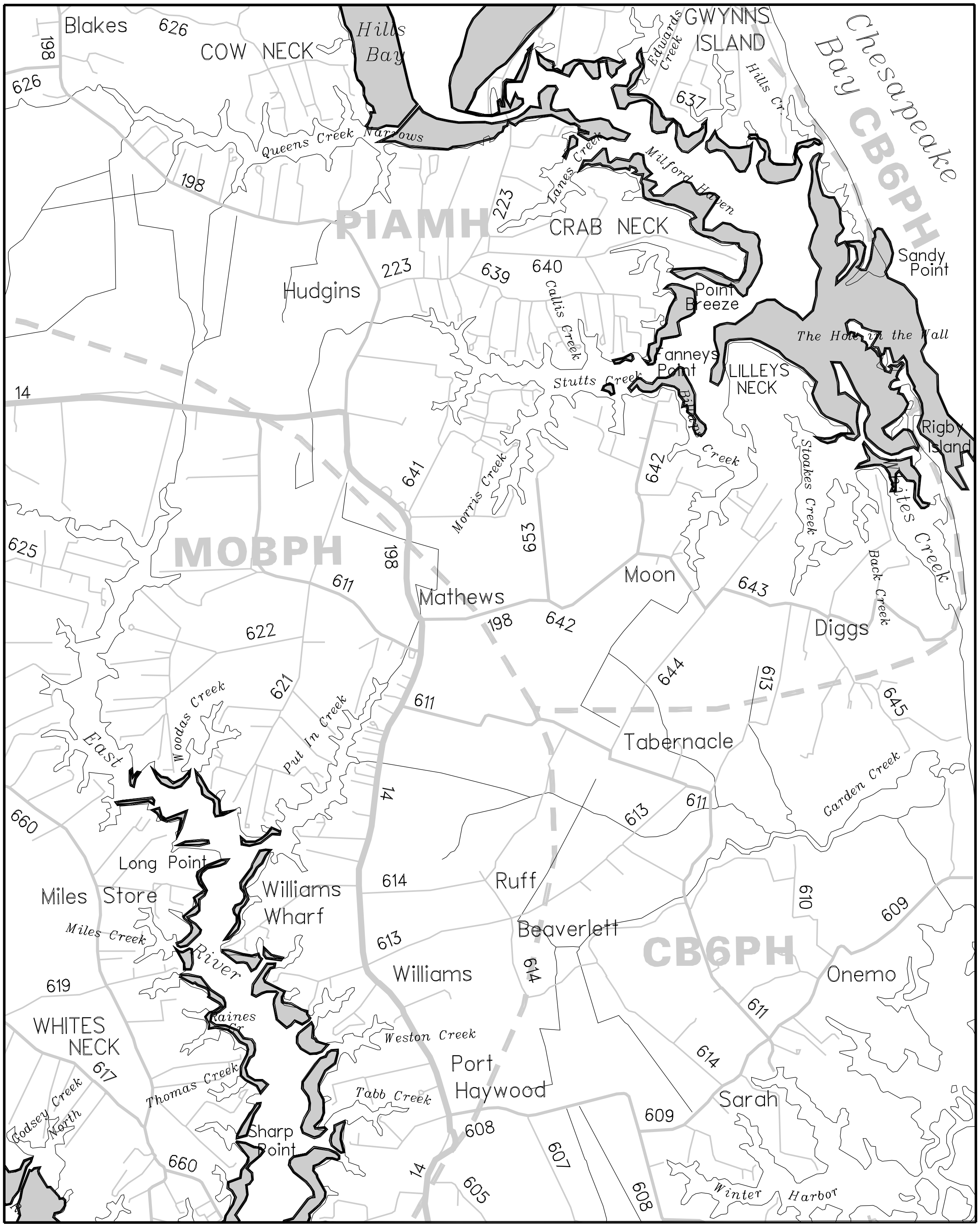
1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Mathews, Va. (123)



Hectares of SAV: 827.37

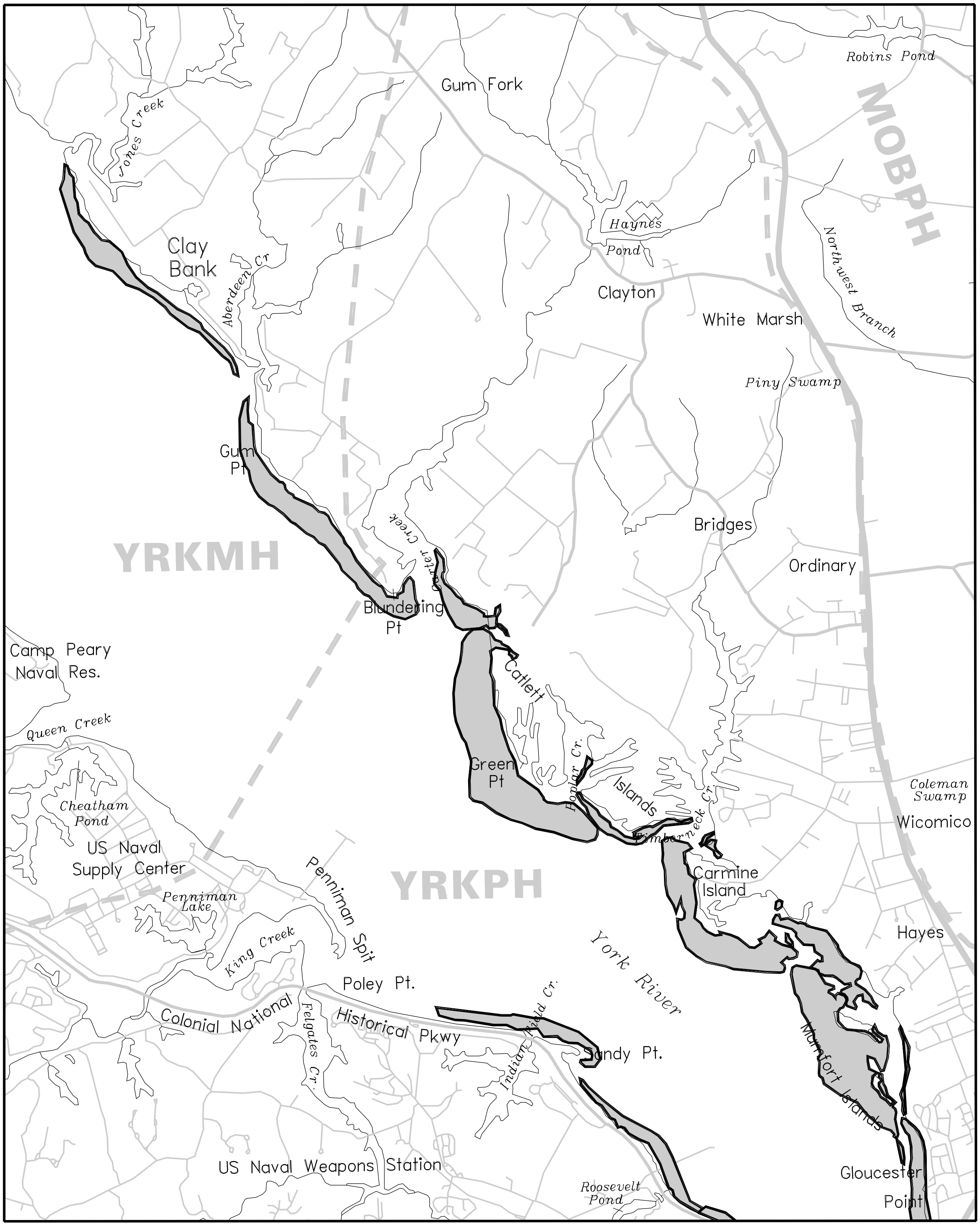
Historical SAV Coverage

1000 0 1000 2000 meters

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Clay Bank, Va. (130)



Hectares of SAV: 546.92

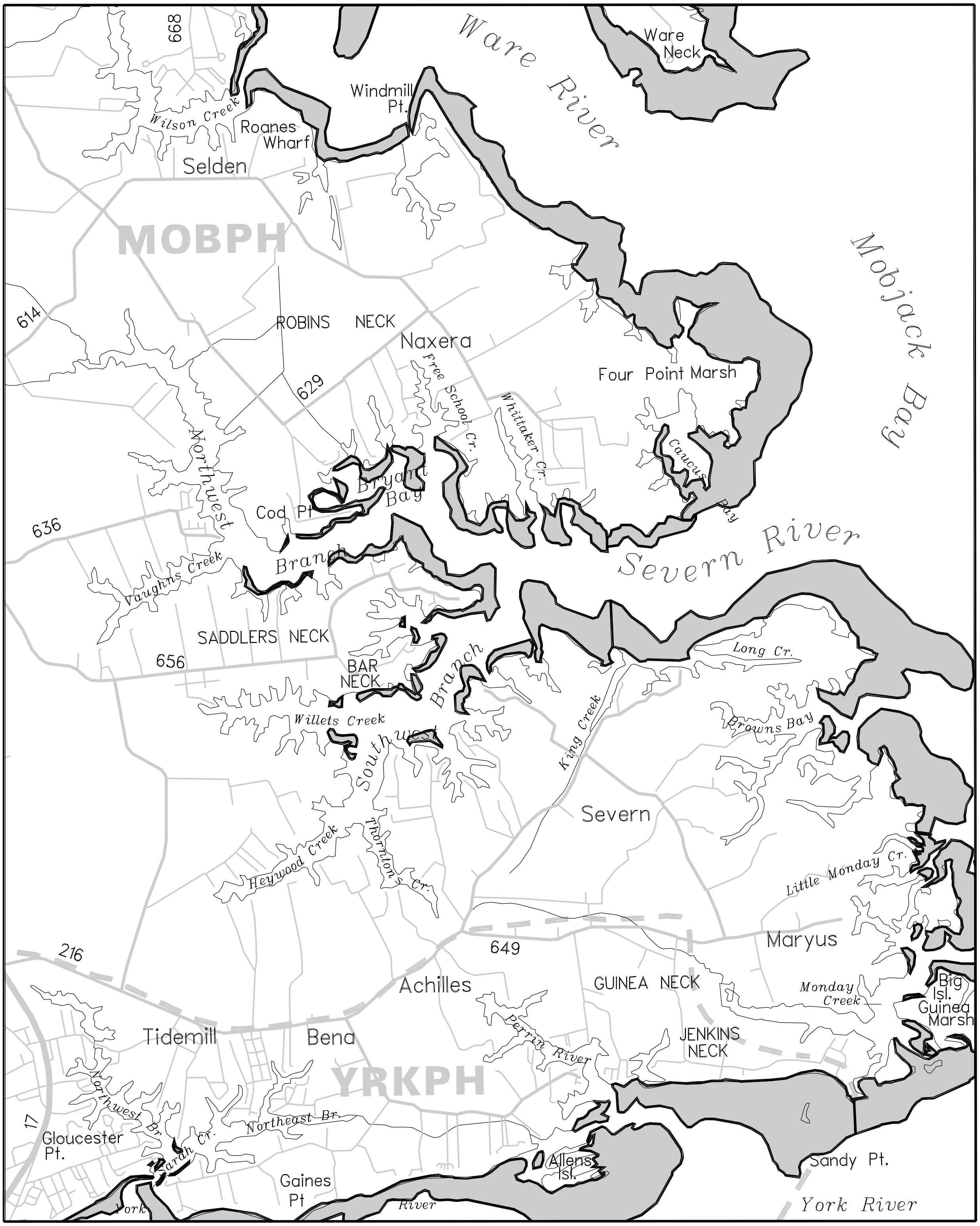
Historical SAV Coverage

1000 0 1000 2000 meters

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Achilles, Va. (131)



Hectares of SAV: 1,629.46

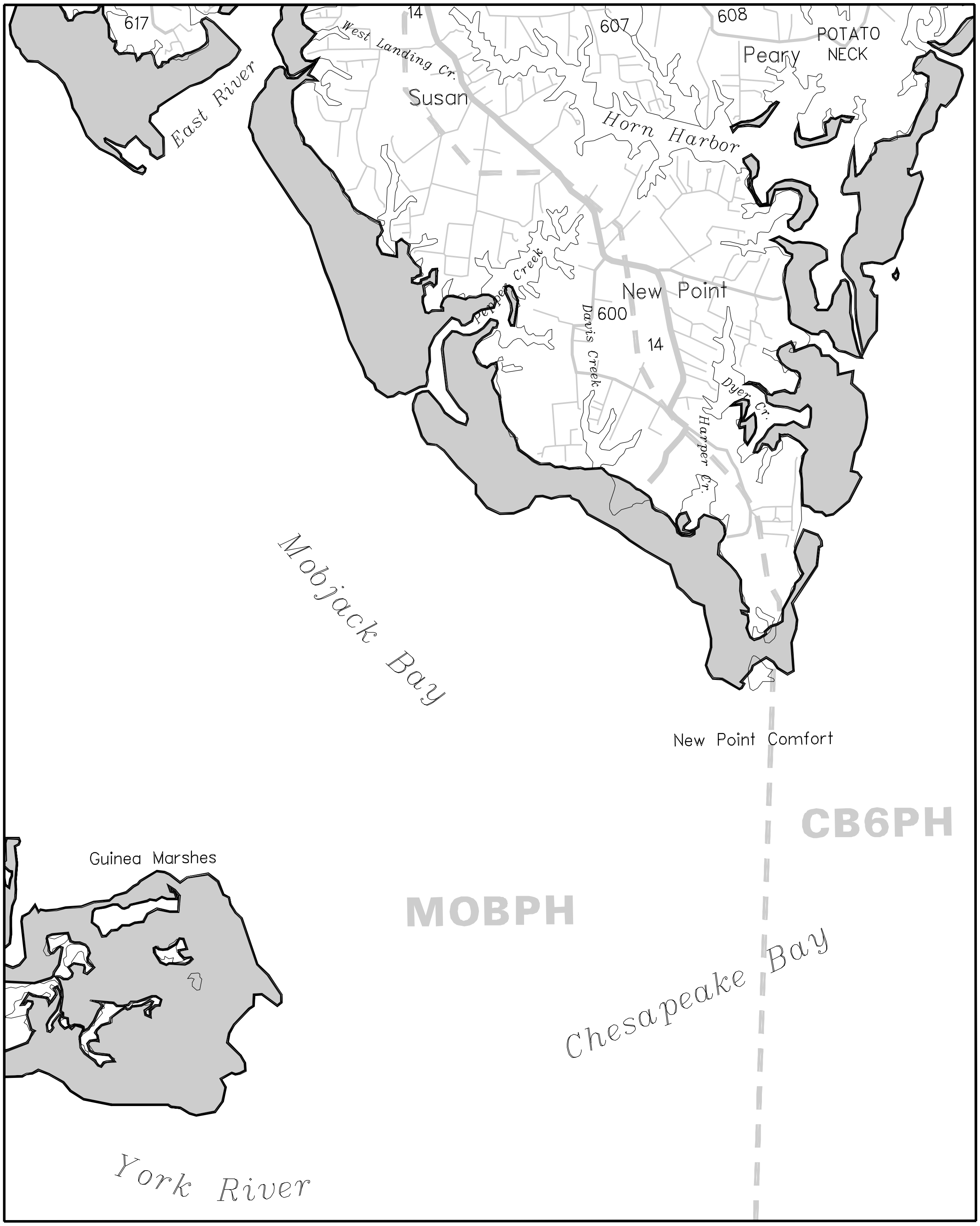
1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

New Point Comfort, Va. (132)



Hectares of SAV: 1,799.82

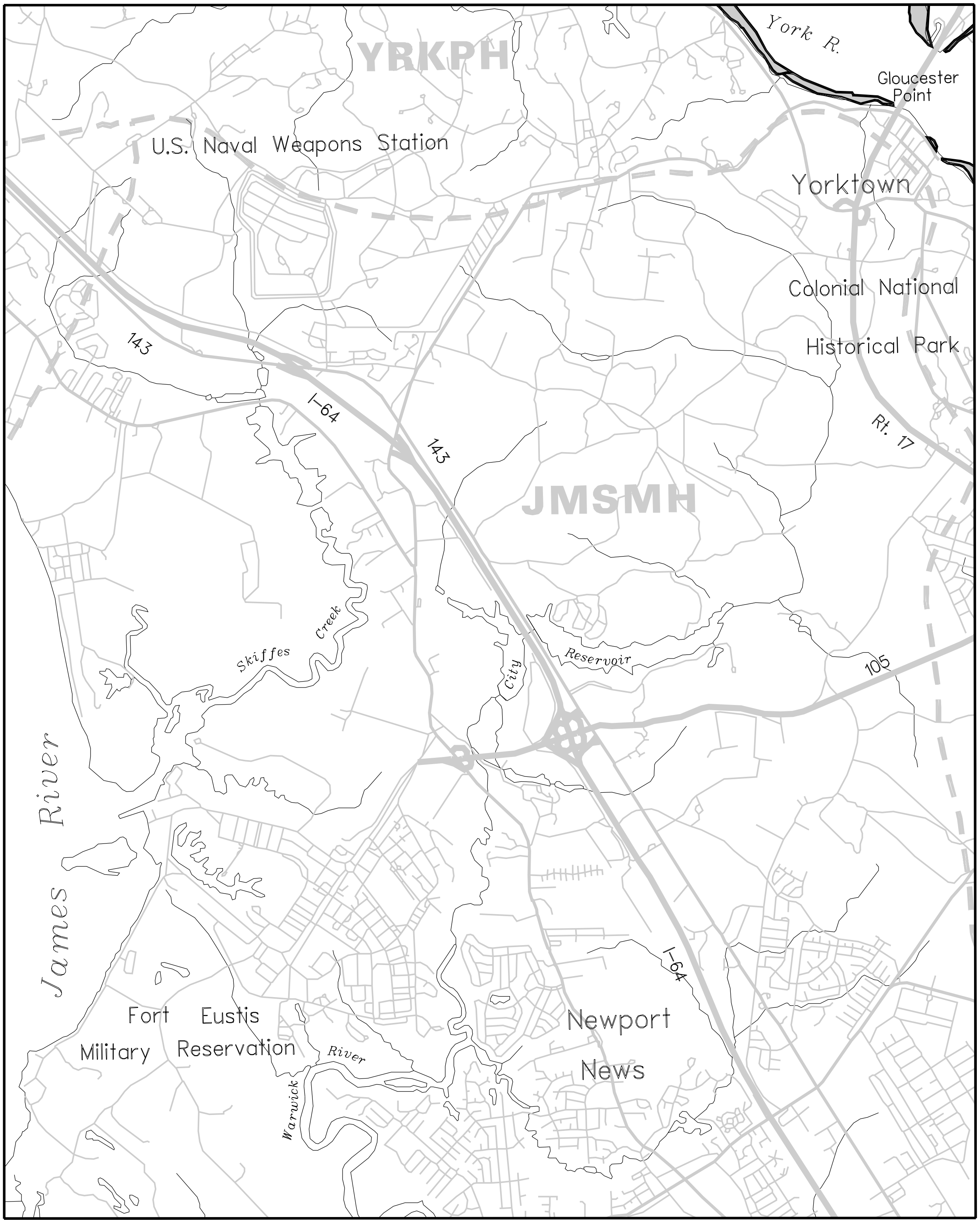
Historical SAV Coverage

1000 0 1000 2000 meters

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Yorktown, Va. (139)



Hectares of SAV: 30.66

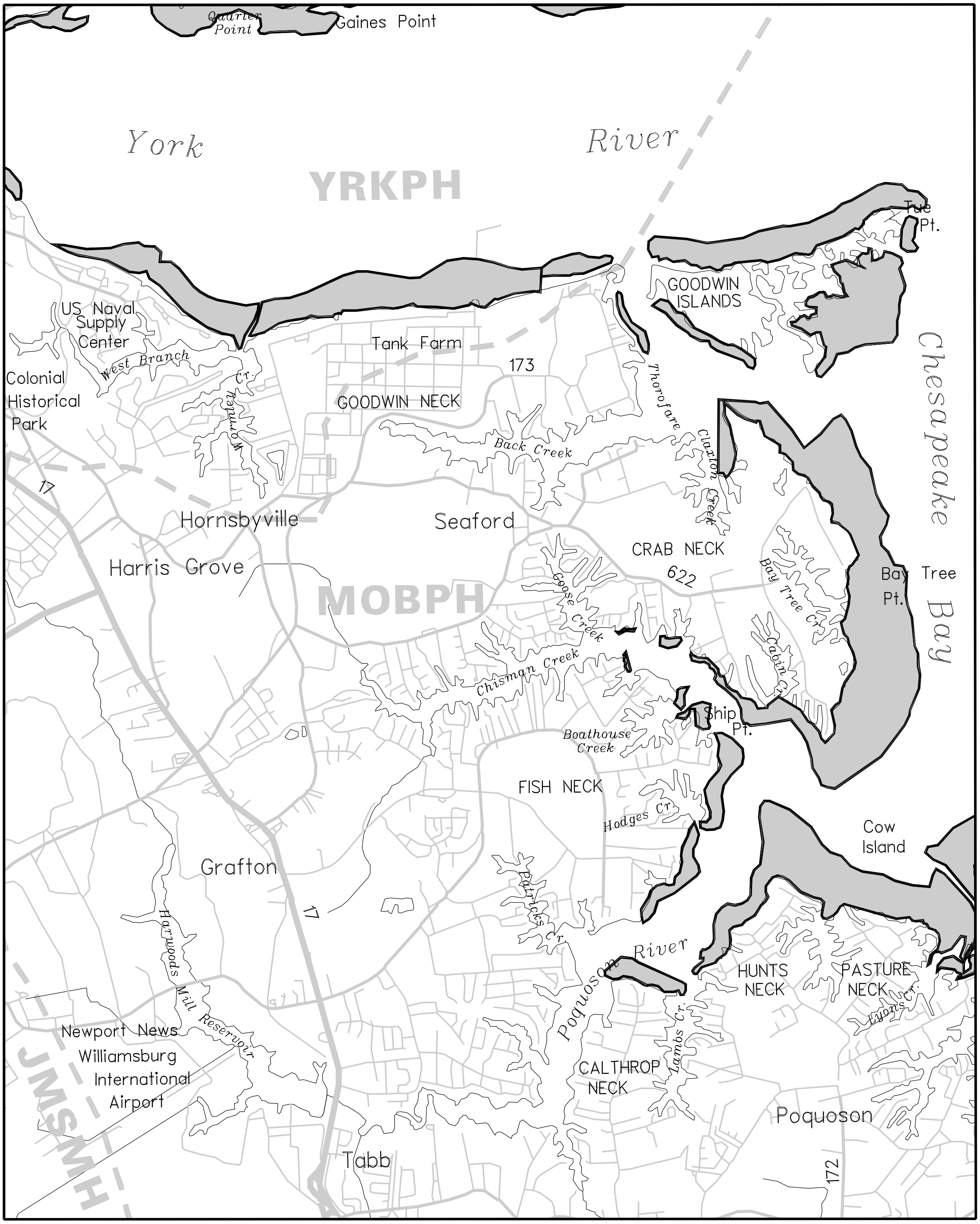
1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Poquoson West, Va. (140)



Hectares of SAV: 1,106.62

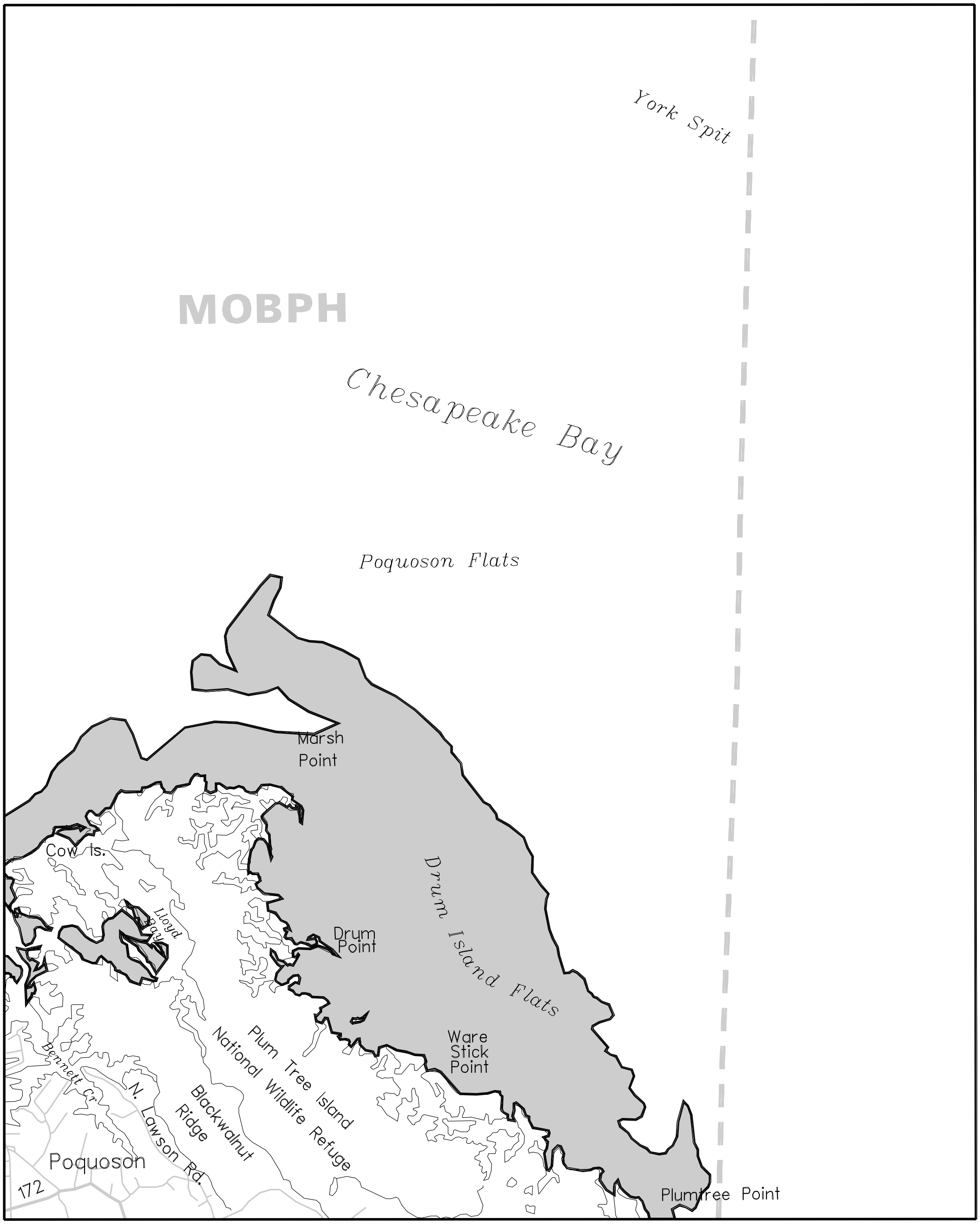
1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Poquoson East, Va. (141)



Hectares of SAV: 1,783.43

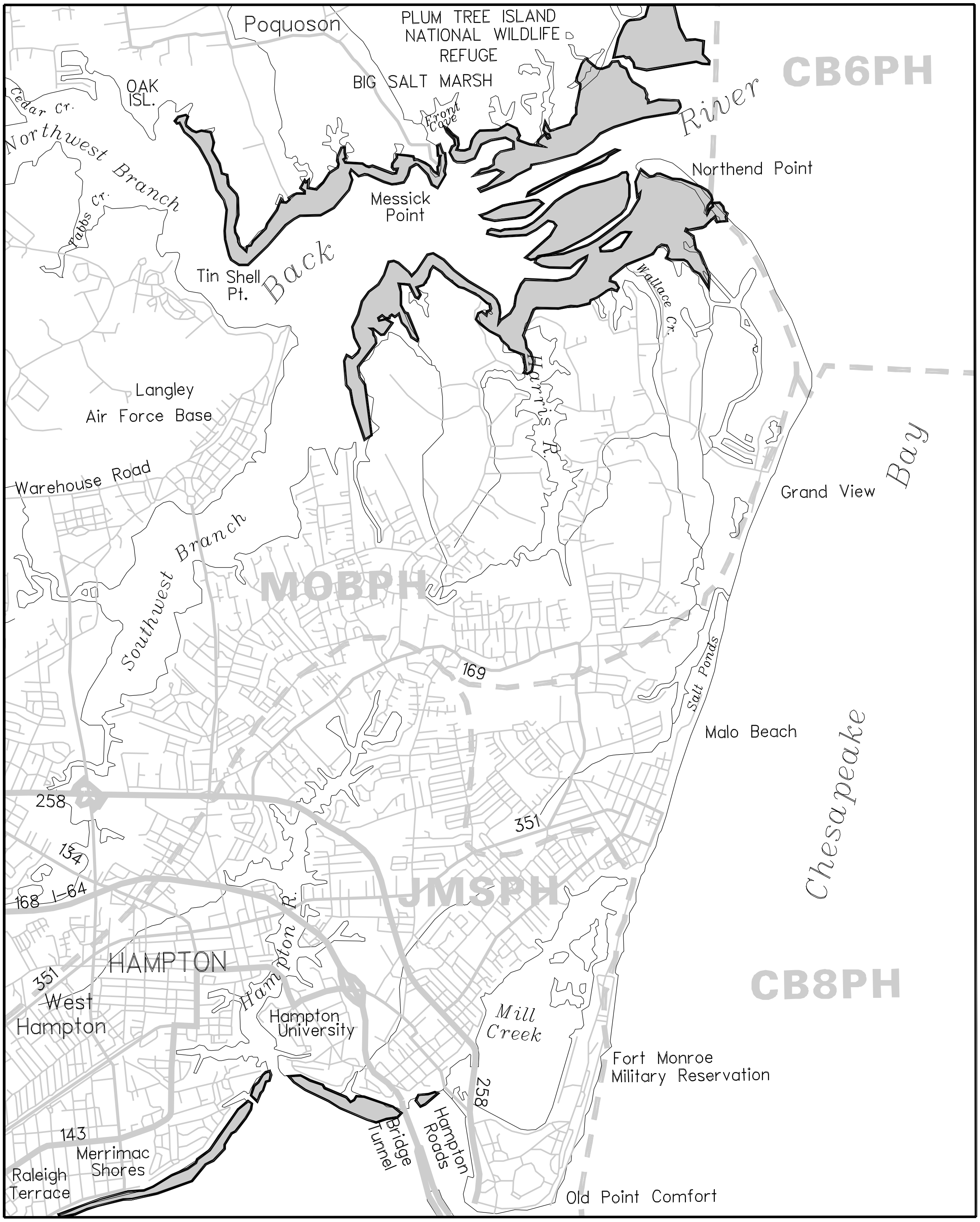
1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Hampton, Va. (147)



Hectares of SAV: 593.74

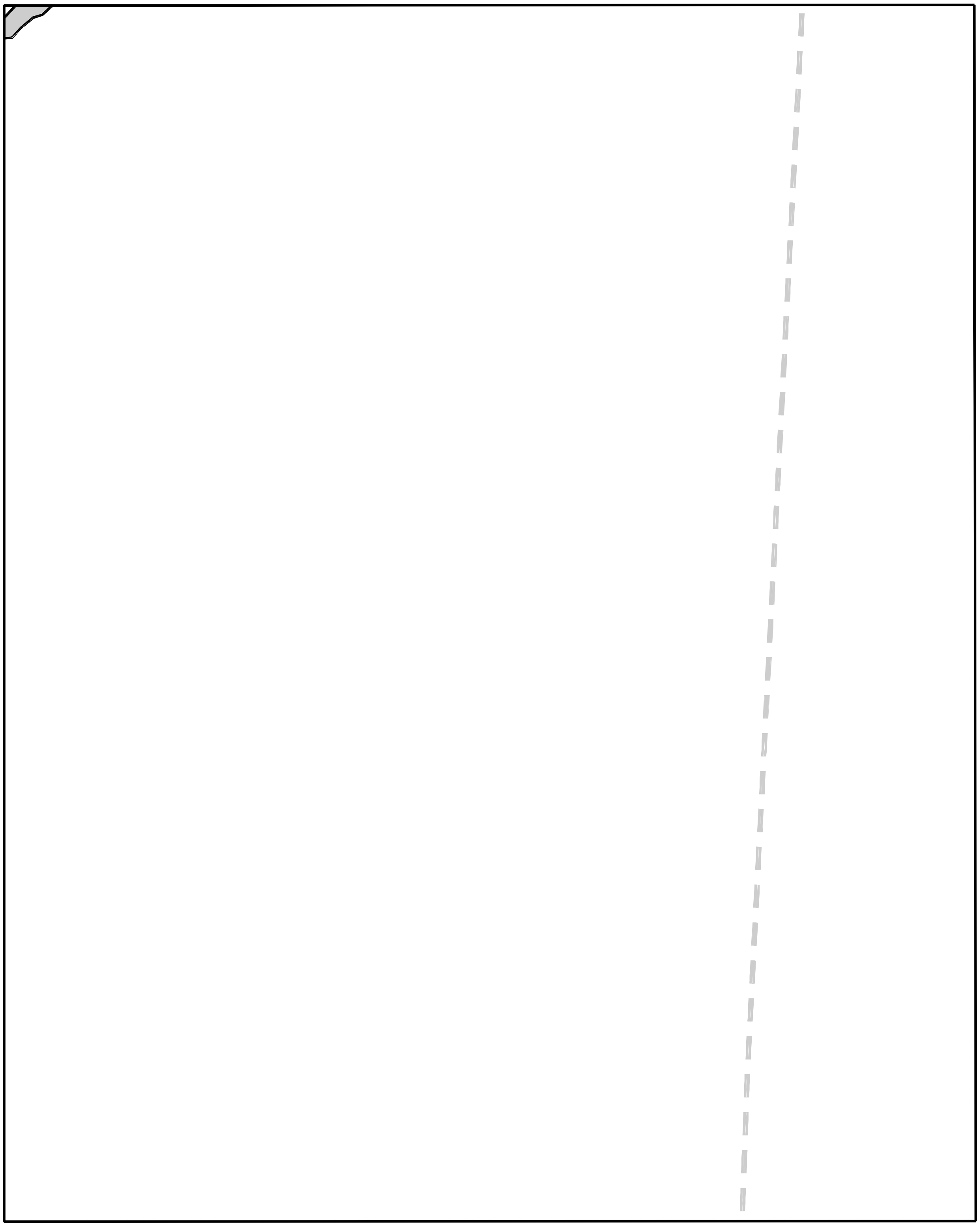
Historical SAV Coverage

1000 0 1000 2000 meters

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

East of New Point Comfort, Va. (177)



Hectares of SAV: 10.15

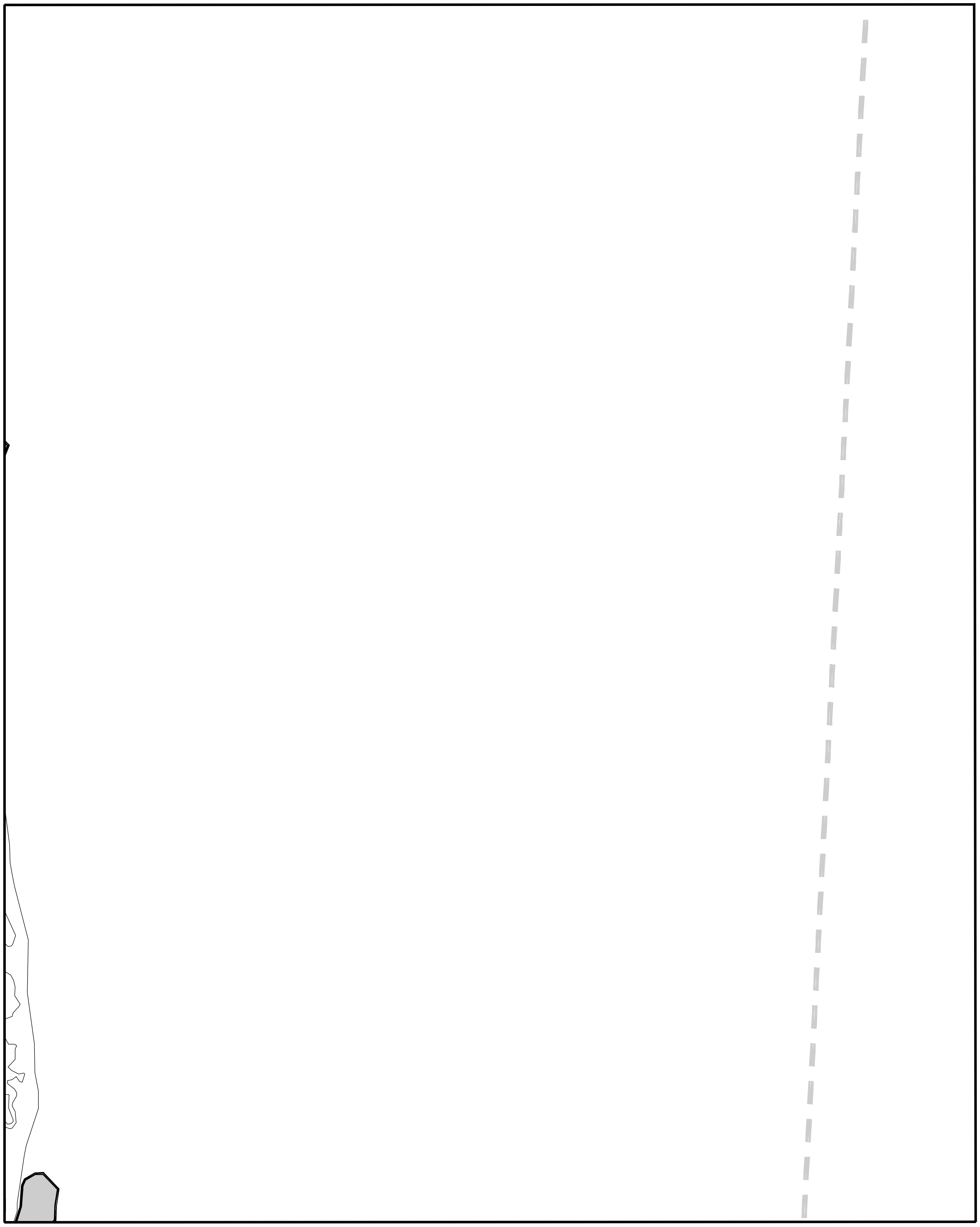
1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Bethel Beach, Va. (178)



Hectares of SAV: 20.93

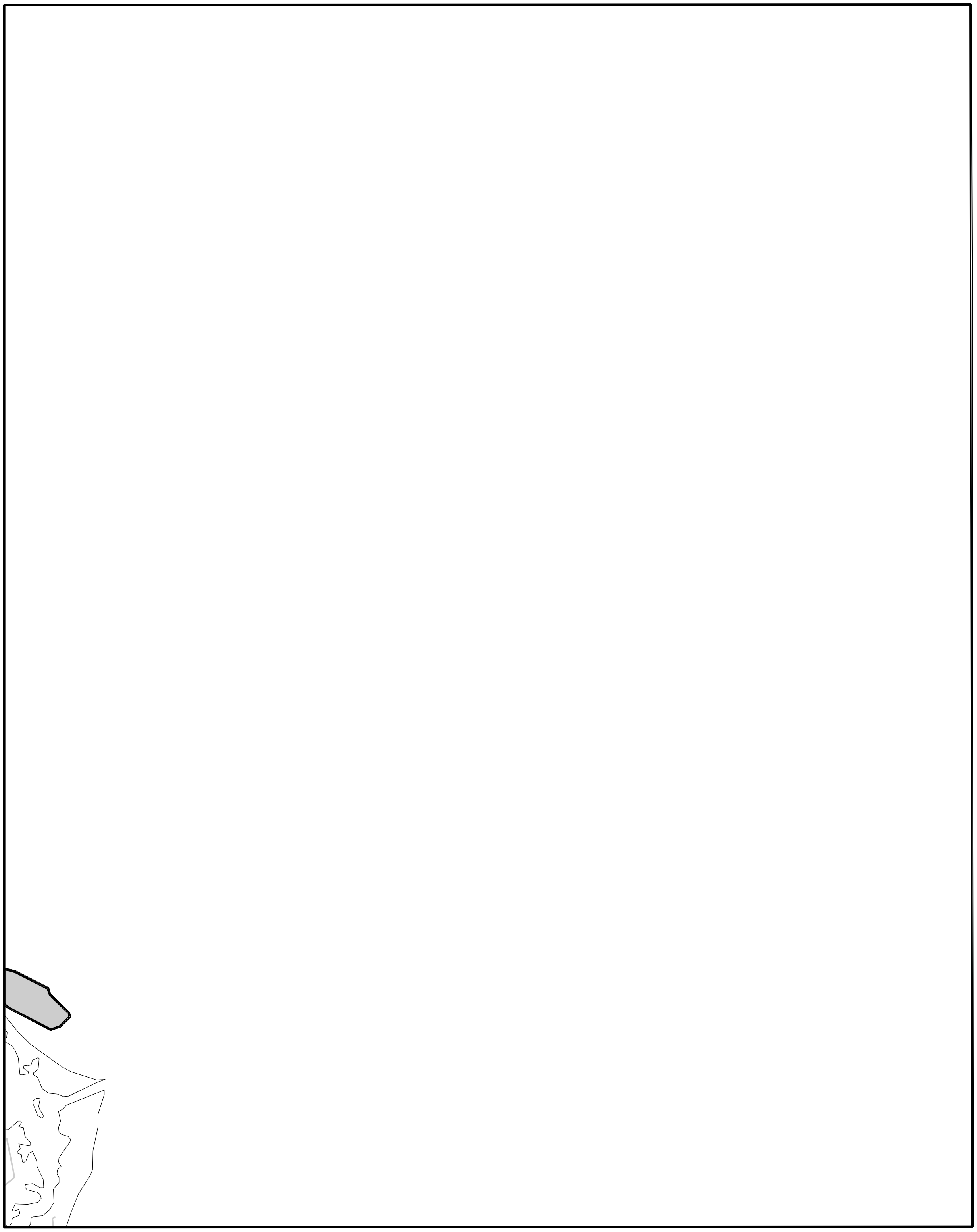
1000 0 1000 2000 meters

Historical SAV Coverage

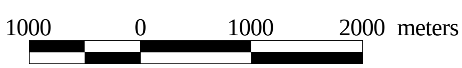
Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

Smith Point, Va. - Md. (182)



Hectares of SAV: 28.62

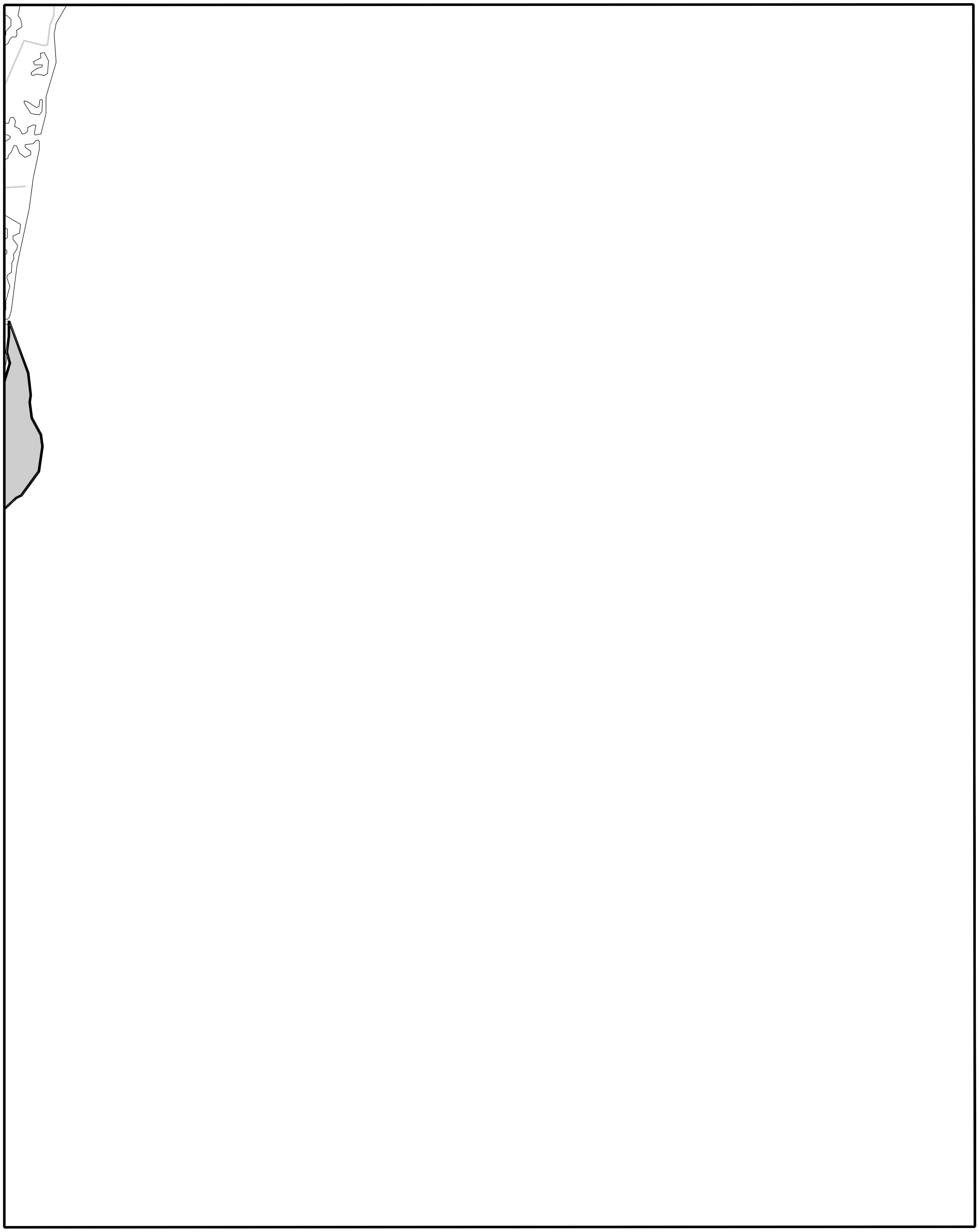


Historical SAV Coverage

Sources: VIMS,USGS

Historical Submerged Aquatic Vegetation

East of Reedville, Va. (183)



Hectares of SAV: 55.21

1000 0 1000 2000 meters

Historical SAV Coverage

Sources: VIMS,USGS