2.2. Maps that Depict Site-Specific Scenarios for Wetland Accretion as Sea Level Rises along the Mid-Atlantic Coast

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Abstract

This paper develops maps and a data set depicting a set of site-specific assumptions for wetland vertical accretion developed by a panel of wetland scientists. The panel had drawn polygons on USGS 1:250,000 scale topographic maps. For each polygon, for each of three sea level rise scenarios, the panel indicated whether tidal wetlands within the polygon would be lost, keep pace, or be marginal. This paper describes how we converted the hard-copy polygons into a GIS database and created a set of maps to concisely depict the panel's findings.

2.2.1. Background

In Section 2.1, Reed et al.[1] explain the basis for an expert panel assessment of the ability of coastal wetlands to keep pace with rising sea level along the mid-Atlantic Coast from the south shore of Long Island to the Virginia/North Carolina border. That assessment was a part of EPA's effort to assess the possible vulnerability of tidal wetlands to rising sea level, which also depends on coastal topography[2] and coastal development.

This paper describes our efforts to create a GIS data layer and maps to depict the panel's assessment. The panel produced a set of marked-up hard copy USGS 1:250,000 scale maps and a set of spreadsheets. We used the hard copy maps to define our polygon boundaries and the spreadsheets to provide descriptions about those polygons (i.e., attributes).[4]

The panel drew polygons on the hard copy maps to approximately identify the areas associated with five primary geomorphic settings, with several subsettings. The USGS 1:250,000 scale topographic maps show roughly where wetlands exist; but they do not delineate the actual wetlands. Therefore, we construed each polygon as representing the panel's intent to identify an area within which all tidal wetlands could be associated with one of the following geomorphic settings or subsettings:

1. Tidal Fresh Forests
2. Tidal Fresh Marsh
3. Estuarine/Brackish Channelized Marshes
    a. Meander
    b. Fringing
    c. Island
4. Back Barrier Lagoon Marsh
    a. Back barrier/Other
    b. Active flood tide delta
    c. Lagoonal fill
5. Saline Marsh Fringe

Each polygon on the maps had an index number. The associated spreadsheets provided:

- Polygon index number
- Region (as described in the panel report)
- Two columns for geomorphic setting and subsetting,
- Three columns for the panel's prognosis for wetland accretion under three alternative sea level rise scenarios
- Place name (optional)
- Special explanation (if appropriate).

The three sea level rise scenarios were current rate, current rate + 2 mm/yr, and current rate + 7 mm/yr. For each of these three scenarios the spreadsheet provided a prognosis for wetland accretion for each polygon. In most cases, the prognosis was one of three possibilities: keeping

[1]Reed, D.J., D.A. Bishara, D.R. Cahoon, J. Donnelly, M. Kearney, Alex Kolker, L.L. Leonard, R. Orson, and J.C. Stevenson. 2008. Site-Specific Scenarios for Wetlands Accretion as Sea Level Rises in the Mid-Atlantic Region. Supporting Document for CCSP 4.1, Question 3. New Orleans, LA: Department of Earth and Environmental Sciences University of New Orleans.

[2]In Chapter 1, Titus and Wang develop a data set and maps expressing coastal elevations relative to spring high water, which is approximately the upper boundary of tidal wetlands. See Titus and Wang, 2008, Maps of Lands Close to Sea Level along the Middle Atlantic Coast of the United States: An Elevation Data Set to Use While Waiting for LIDAR, in *Background Documents Supporting Climate Change Science Program Synthesis and Assessment Product 4.1: Coastal Elevations and Sensitivity to Sea Level Rise*, EPA 430R07004, Washington, DC: U.S. EPA.

[4]In a GIS polygon layer, an attribute table associates information with each polygon.

pace, marginal, and loss (see Section 2.1, Reed et al. for description). In a few cases, however, the panel's original assessment was "marginal/loss" for a particular sea level rise scenario.[5]

2.2.2. Conversion of the Panel's Output to a GIS Dataset

Our final data set provides two layers:

- "Raw" consists of the polygons created by the panel (and the associated attributes), which identify the geomorphic setting.
- "Wetlands" is a coastal wetlands data set, with attributes that identify the geomorphic settings and wetland accretion potential as defined by the panel.

The Raw Data

Our objective was to convert the hand renderings into a digital data set suitable for use in a GIS. The polygons provided by the panel included tidal wetlands, nontidal wetlands, dry land, and open water; but the information developed by the panel applies only to the tidal wetlands within the polygon. We also inspected the results of our digitizing to identify and remedy those cases where a literal digital conversion of what the panel drew was inconsistent with the panel's intent. For example, the polygon boundaries did not include all of the tidal wetlands in some areas, because the USGS 1:250,000 scale topographic maps do not show all wetlands or indicate the head-of-tide (above which wetlands are nontidal).

The first step toward creating a data set was to create a tracing of the polygons according to a procedure developed by Russ Jones. The key aspects were to faithfully trace the panel polygons and the registration marks from the USGS maps. Dana Bishara of the University of New Orleans overlayed Mylar sheets on top of the 1:250,000 USGS maps and manually traced the polygons and registration marks, and sent them to Jones.

The second step was to digitize the polygons. Jones provided the Mylars to Digital Data Services, Inc. (Lakewood, Colorado), who scanned them to a digital format in color at 300 dots per inch in Tagged Image File Format (tif). Richard Streeter digitized the polygons into a GIS using raster-to-vector conversion software.[6] See Figure 2.2.1.

The third step was to overlay the polygons with a wetlands data set. Jones and Streeter created quad-specific maps in a GIS by overlaying the polygons on top of the EPA coastal wetlands data set (Chapter 1, Titus and Wang, see note 2). Figure 2.2.2 shows the initial "raw" product from this overlay, for the Salisbury (Maryland) quadrangle.

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[5] These cases were all either along the South Shore of Long Island or in the Virginia Beach/Chesapeake area.

[6] ESRI, 2005, ArcScan software, v. 9.1, Redlands, CA: Environmental Systems Research Institute.

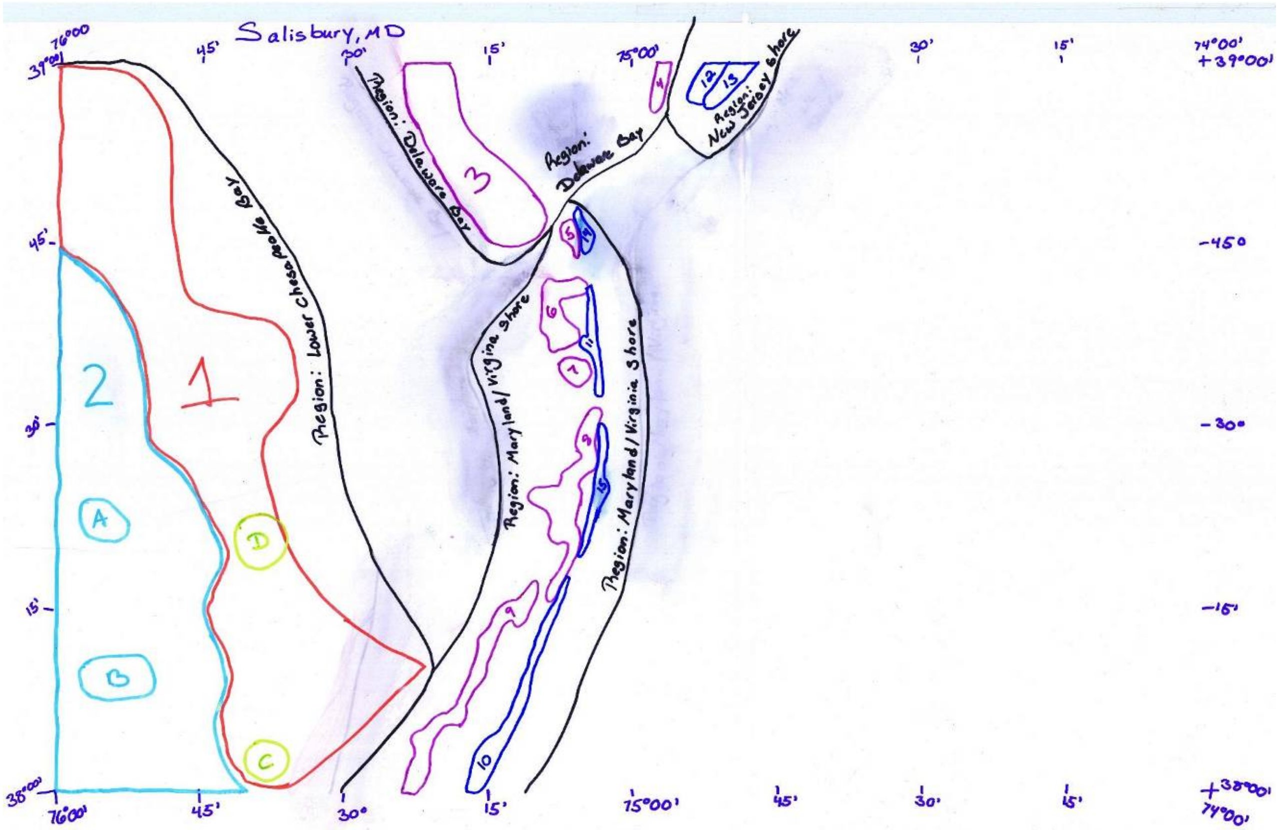


Figure 2.2.1. Polygons Created by Wetland Accretion Panel Assessment: Salisbury Quadrangle. The wetland accretion panel drew polygons on 1:250,000 USGS quads. Panel staff then traced the polygons onto Mylar. The black lines define subregions; the other colored lines define polygons representing wetlands of a given geomorphic setting.

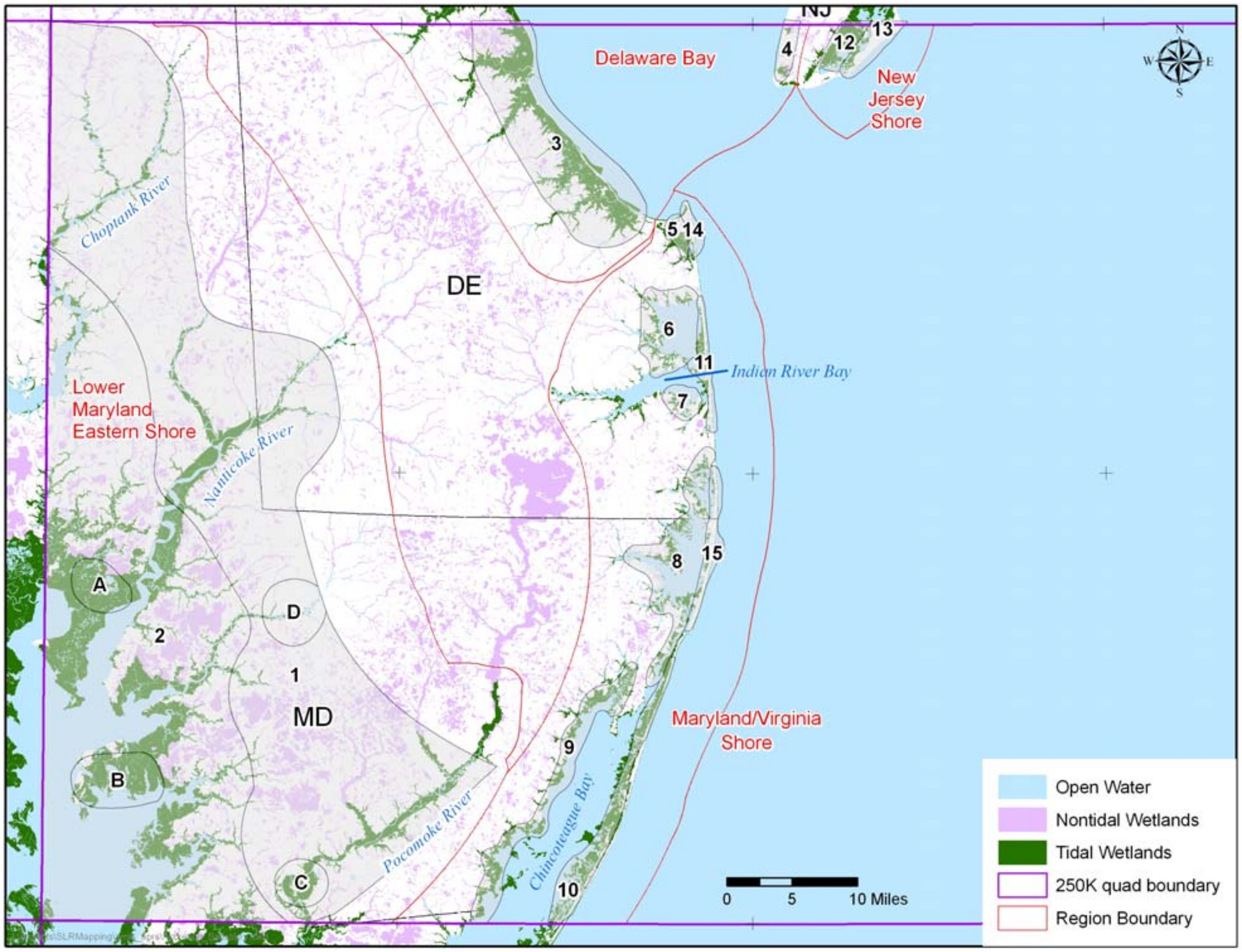


Figure 2.2.2. Overlay of the Polygons from Wetland Accretion Panel with a Wetlands Data Set: Salisbury Quadrangle. Each of the shaded polygons has an index number or letter; wetlands outside the shaded polygons were unassigned and had to be corrected. The light red lines that are not the boundary of a shaded polygon delineate the subregional boundaries. Note that that the shaded polygons do not include all of the tidal wetlands along Chincoteague and Indian River bays, nor the upper portions of the Choptank, Nanticoke, and Pocomoke rivers.

The fourth step was quality control of the polygons created by the panel. Figure 2.2.2 shows some of the issues that we addressed in this step. In many cases, tidal wetlands[7] lie outside of the geomorphic regions defined by the polygons, and assignments of geomorphic regions did not match local conditions (e.g., active flood tide deltas were not adjacent to inlets). In some cases, the tidal wetlands extended farther inland than the polygons. See, for example, the tidal wetlands that are not included in a shaded polygon to the west (inland) of polygon #3 along Delaware Bay; the extensive tidal wetlands along Rehoboth Bay (i.e., the bay between polygons #6 and #7), and the tidal wetlands along the upper Pocomoke River (i.e., the river that runs through polygon #C). In other cases, wetlands extend farther into the coastal lagoons than the polygons drawn by the panel indicated (e.g., the wetlands along polygons #9 and #10). In some cases, the original polygons omitted wetland areas, particularly in the upper reaches of estuaries; so we had no information on geomorphic setting or wetland accretion potential for wetlands in those areas (see Figures 2.2.2 and 2.2.3).

In general, the panel's polygon boundaries needed correction for several reasons:

[7]Titus and Wang (see note 2) generated a wetlands data set from a combination of National Wetlands Inventory wetlands and state wetlands data sets.

(a) Maps using a coarse 1:250,000 scale routinely show "scale mismatch" when overlaid with data created at a finer resolution.
(b) The panel's polygon boundaries often omitted large areas of wetlands, because the USGS 1:250,000 maps do not show all wetlands.
(c) In some cases, the polygon boundaries did not track the landforms originally intended (e.g., the polygon around an inlet on the 1:250,000 scale map covering open water and missing the wetlands). This occurred primarily because the polygons that the panel had drawn were in many cases drawn to be "indicative" rather than precise; e.g., on the 1:250,000 map, the polygons boundaries as drawn sometimes differed from the actual boundary by approximately 1 cm.
(d) The panel did not have a watershed map, and in some cases the boundaries that they drew unintentionally crossed watershed boundaries or split a boundary. Many of these errors were apparent with the wetlands overlay.

We brought these cases to the attention of Reed and Bishara, who used our overlay to hand-edit the polygon boundaries to more closely follow the landforms and thus reflect the original intent of the panel. Streeter digitized the changes into the GIS. We then examined the maps a final time and made a small number of additional corrections. For example, in Figure 2.2.3, some tidal wetlands were not part of any "polygon" in the original panel output. The hand-edits assigned all of those wetlands to the same categories as the adjacent estuarine wetlands. Along the Christina River, this left us with estuarine wetlands upstream from freshwater wetlands; so we readjusted polygon 5 to include the upper portion of the tidal river. The net effect of these changes was to ensure that all tidal wetlands would be included in one of the shaded polygons, and associated with the correct landform and assigned region.

Wetlands Data Set

Our fifth step was to convert the raw data into a wetlands data set. This step involved both data processing and some cartography. Our data processing step involved importing the spreadsheets of attributes provided by Reed into the GIS and joining to the polygon layer via the index number that was common to both files. Finally, we transferred the attributes in the panel polygons to the EPA coastal wetlands data generated by Titus and Wang via a simple overlay function within the GIS. The final output of this fifth step is a polygon wetland data set with attributed defining geomorphic setting, accretion potential, and subregion. Figure 2.2.4 is an example of the resulting map.

2.2.3 Creating Maps from the Data

The cartographic step involved devising a reasonable way to portray the results of the panel assessment. The three main issues we considered were readability of small polygons, map colors, and the map legend.

Readability of Small Polygons

The purpose of the map is to show *where* wetlands are likely (or unlikely) to keep pace with sea level rise. We decided early on to use wetlands data rather than regional boundaries, because the area and location of wetlands is an important consideration. In places where the wetlands are a narrow fringe or widely dispersed islands, they are likely to be too small to be seen on a statewide map drawn to scale—not to mention a map of the entire mid-Atlantic. We looked at test maps drawn to scale, and the freshwater tidal wetlands along the Potomac and Delaware rivers were particularly hard to see.

Therefore, in printing these maps, we set the line widths to be scale-independent, to accentuate small areas. The net effect is that every tidal wetland polygon displays on our maps (unless overlaid with another wetland polygon).

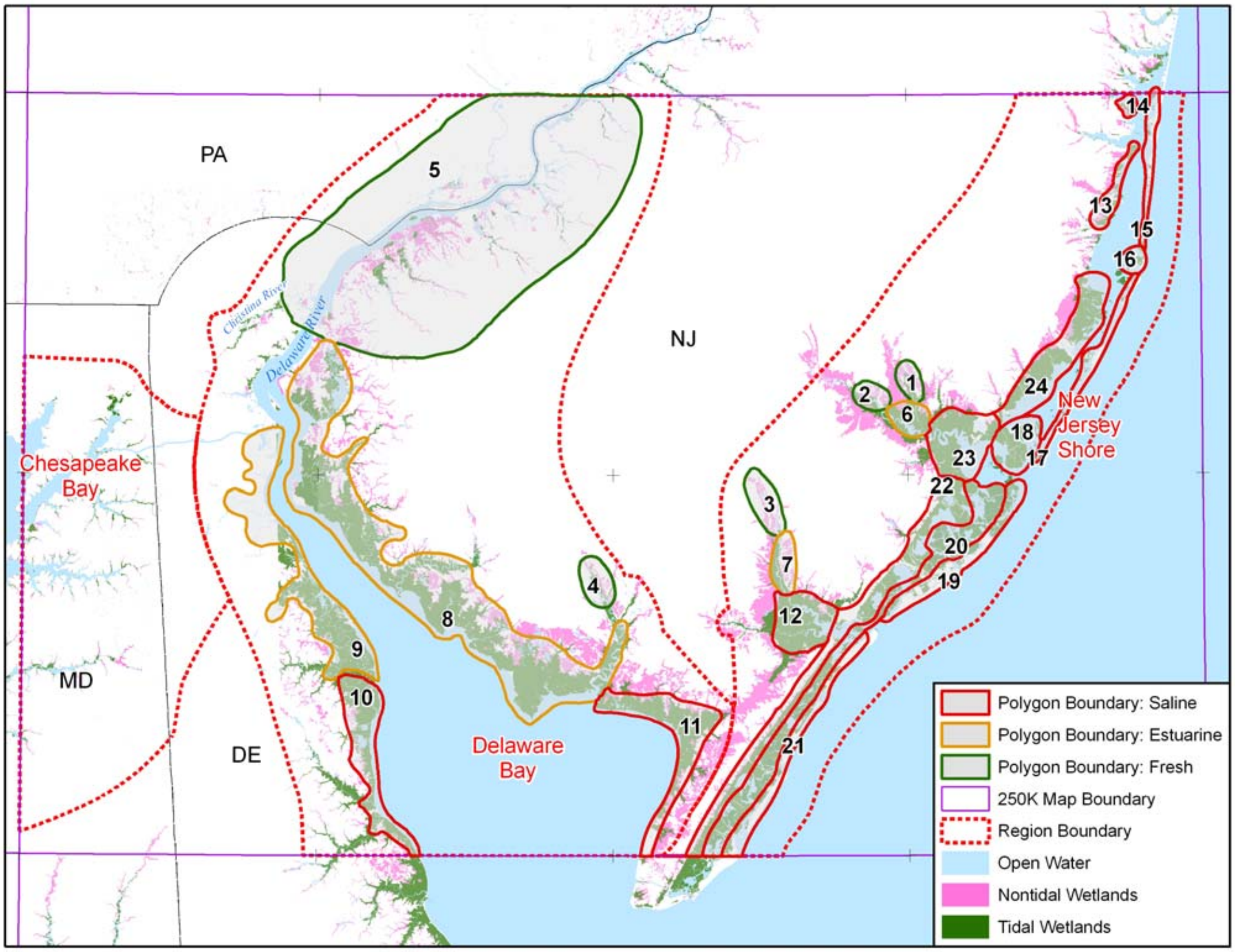


Figure 2.2.3. Overlay of the Polygons from Wetland Accretion Panel and Wetlands Data Set: Wilmington Quadrangle. The fresh/saline interface in the Delaware River is generally viewed as located near the Delaware/Pennsylvania border. But freshwater wetlands extend farther downstream, according to the panel. Polygon 5 represents the freshwater tidal marshes of the Delaware River watershed; the panel viewed the rest of the wetlands in the Delaware River watershed as estuarine marsh. Although the mouth of the Christina River into the Delaware River (southwest end of polygon 5) is in the freshwater marsh, the upstream portions of the river are shown as being estuarine marsh. We treated this as unintentional and altered the boundaries to show this entire river as freshwater marsh. Note also that that polygons denoting wetland zonation do not include all of the tidal wetlands on the Delaware side of the Delaware River and Bay.

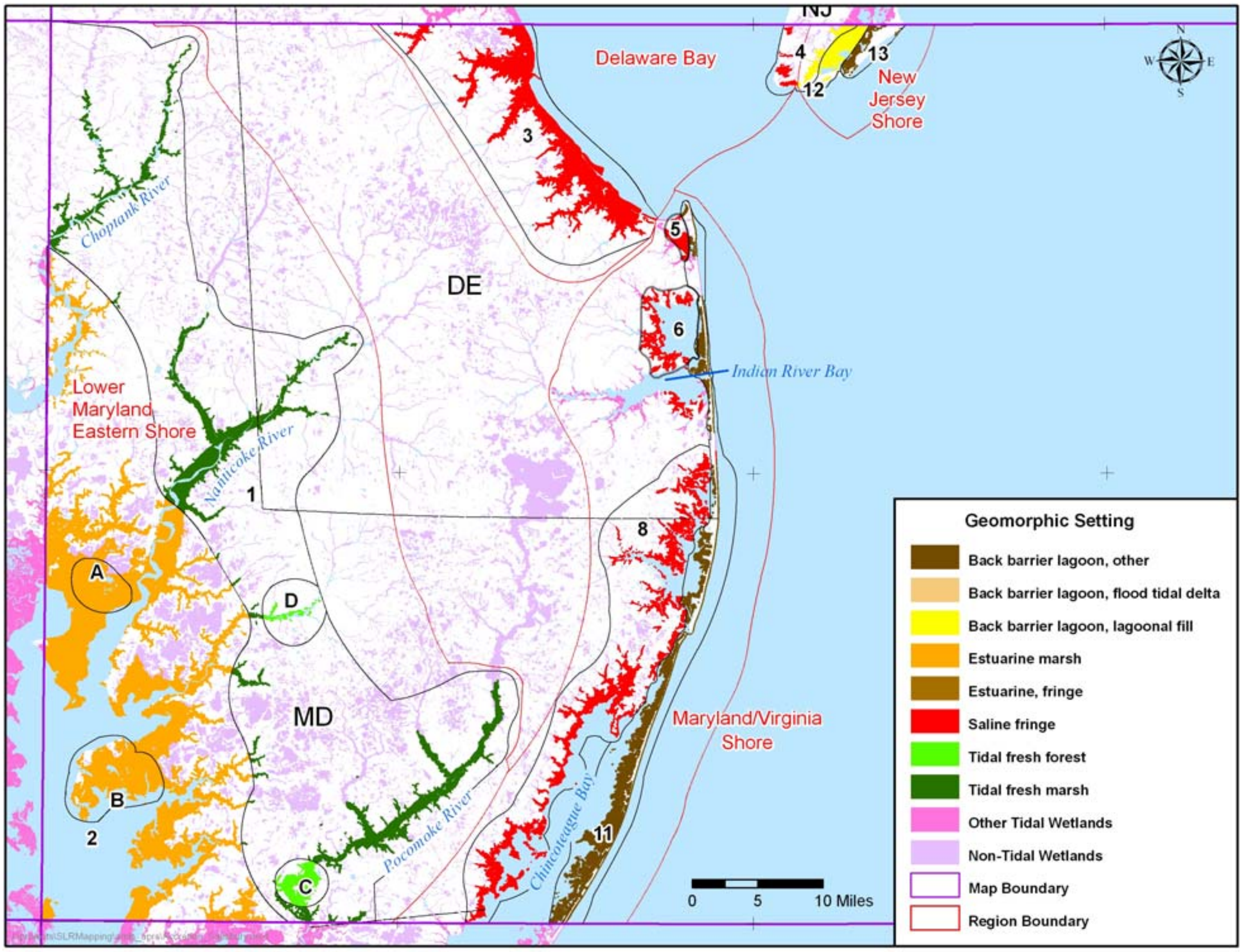


Figure 2.2.4. Wetland data displayed based on attributes provided by the panel for geomorphic setting. By this point, polygon boundaries had been revised to include most tidal wetlands. Compare with Figure 2.2.2. A few revisions were still needed, such as along Indian River Bay, where some tidal wetlands were still outside the polygon boundaries.

Expectation	Color	Reason for Color
Loss even at current rates:	Blue	Because it is becoming water anyway
Marginal today, loss at +2 m/yr:	Red	The standard color for a warning
Keeping pace today, marginal at 2 mm/yr, loss at 7 m/yr	Brown	A common color for environmental risk
Keep pace +2 mm/yr, loss at +7 mm/yr	Yellow Brown	A compromise between brown and green
Keeping with +2 mm/yr, marginal at +7 mm/yr	Light green	Wetlands likely to survive, stay green
Keeping pace at +7 mm/yr	Bold green	Wetlands very likely to survive (remain green)

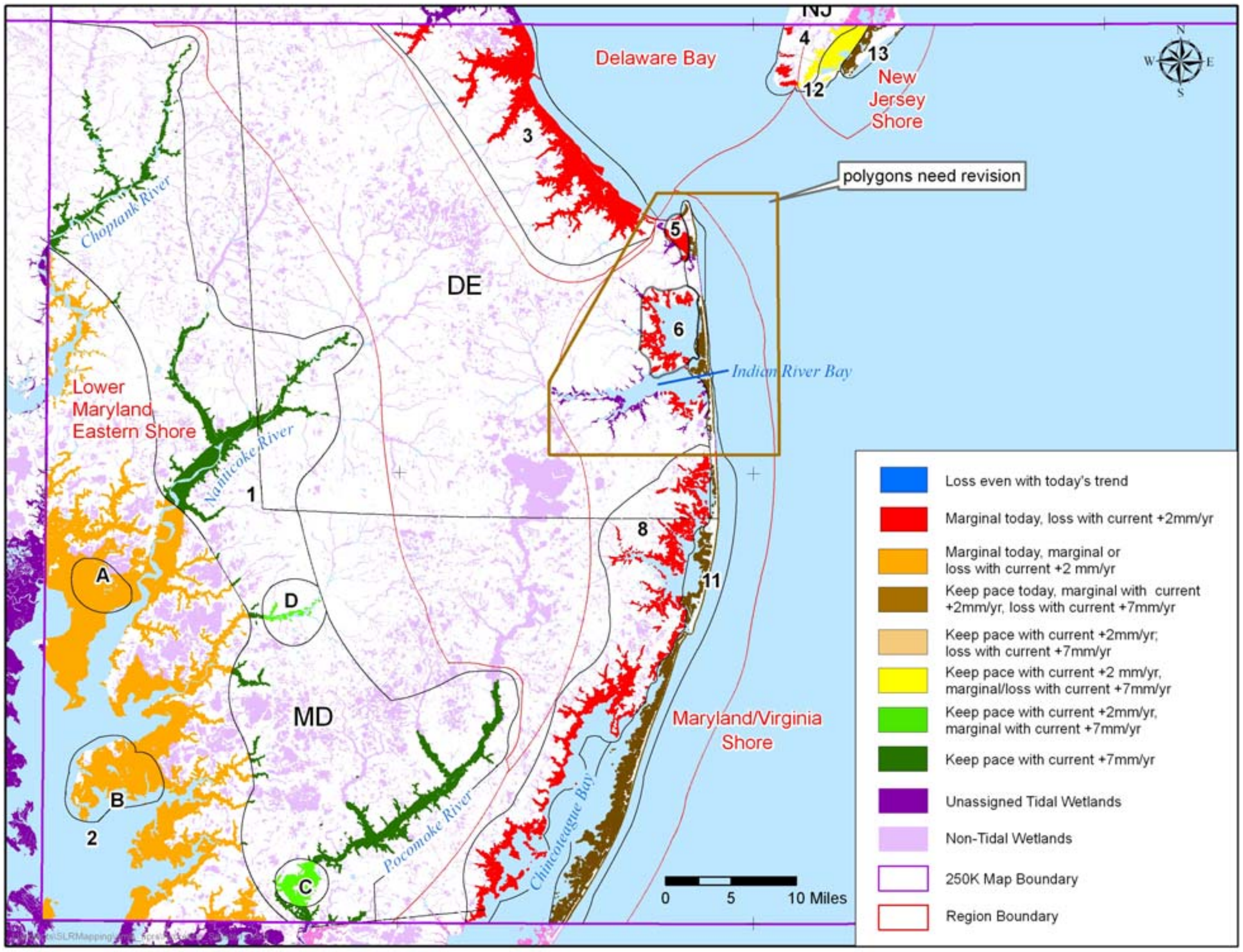


Figure 2.2.5. Wetland Accretion potential for polygons in the Salisbury quad. At this point, the polygons still needed revision around Indian River Bay.

Map Colors

The panel provided one of five accretion possibilities (keep pace, marginal/keep pace, marginal, marginal/loss, loss) for each of three sea level rise scenarios. That specification seemed to suggest a map for each sea level rise scenario—which could lead us to an unwieldy proliferation of maps. Putting all the information on a single map seemed more desirable. Fortunately, only 8 of the possible 15 combinations (5 accretion sensitivities by 3 sea level scenarios) occurred, a manageable number of colors.[8] Ignoring the areas of uncertainty (e.g., marginal/loss) actually leaves us with only 6 sensitivities, for which we defined the following colors.

We then defined intermediate colors for two other, more intermediate specifications: marginal today, marginal/loss at current +2 mm/yr, loss at current + 7 mm/yr (orange) and keep pace with current + 2 mm/yr and marginal/loss at current + 7 mm/yr (yellow). Figure 2.2.5 shows the resulting map for wetland accretion. The zipped file with which this data is distributed includes jpg's for the quads and the regions, as well as an overview map, following that color scheme. The reader may notice that the polygon boundaries and map colors in Figures 2.2.4 and 2.2.5 have been assigned to most of the tidal wetlands that had been omitted from the polygons in Figure 2.2.2. However, some of the wetlands around Rehoboth Bay were still unassigned. Similarly,

[8]During an initial review, the total number of combinations was reduced to 7, because the only polygon where wetlands were marginal at +7 mm/yr had been erroneously denoted as such. We've left that combination within the legend bar because it is an obvious possibility that may emerge during subsequent review or in other study areas.

assigning the map colors allowed us to notice a number of errors. We queried the data to identify all wetlands that had not been assigned a geomorphic setting, and looked for other cases where the geomorphic setting had a clear map boundary error.[9] We corrected the polygons based on our understanding of the panel's intent as documented by Reed et al. (see note 1).

Legend

One problematic aspect with maps following the format of Figure 2.2.5 is that the keys take a lot of words to repeat the same concepts. A single color bar would be preferable; but the panel did not characterize the wetlands with a single condition. We experimented with a pair of color bars, but people found that approach too confusing. The simplest alternative to a lot of words appears to be a table, with a color bar. (See Figure 2.2.6.)

Will Wetlands Be Converted to Open Water?								
Rate of Sea Level Rise	(blue)	(red)	(orange)	(brown)	(tan)	(yellow)	(light green)	(dark green)
Current rate	Yes	?	?	No	No	No	No	No
Current + 2 mm/yr	Yes	Yes	Yes?	?	No	No	No	No
Current + 7 mm/yr	Yes	Yes	Yes	Yes	Yes	Yes?	?	No
? = Wetlands would be marginal Yes? = Wetland would be marginal or lost								

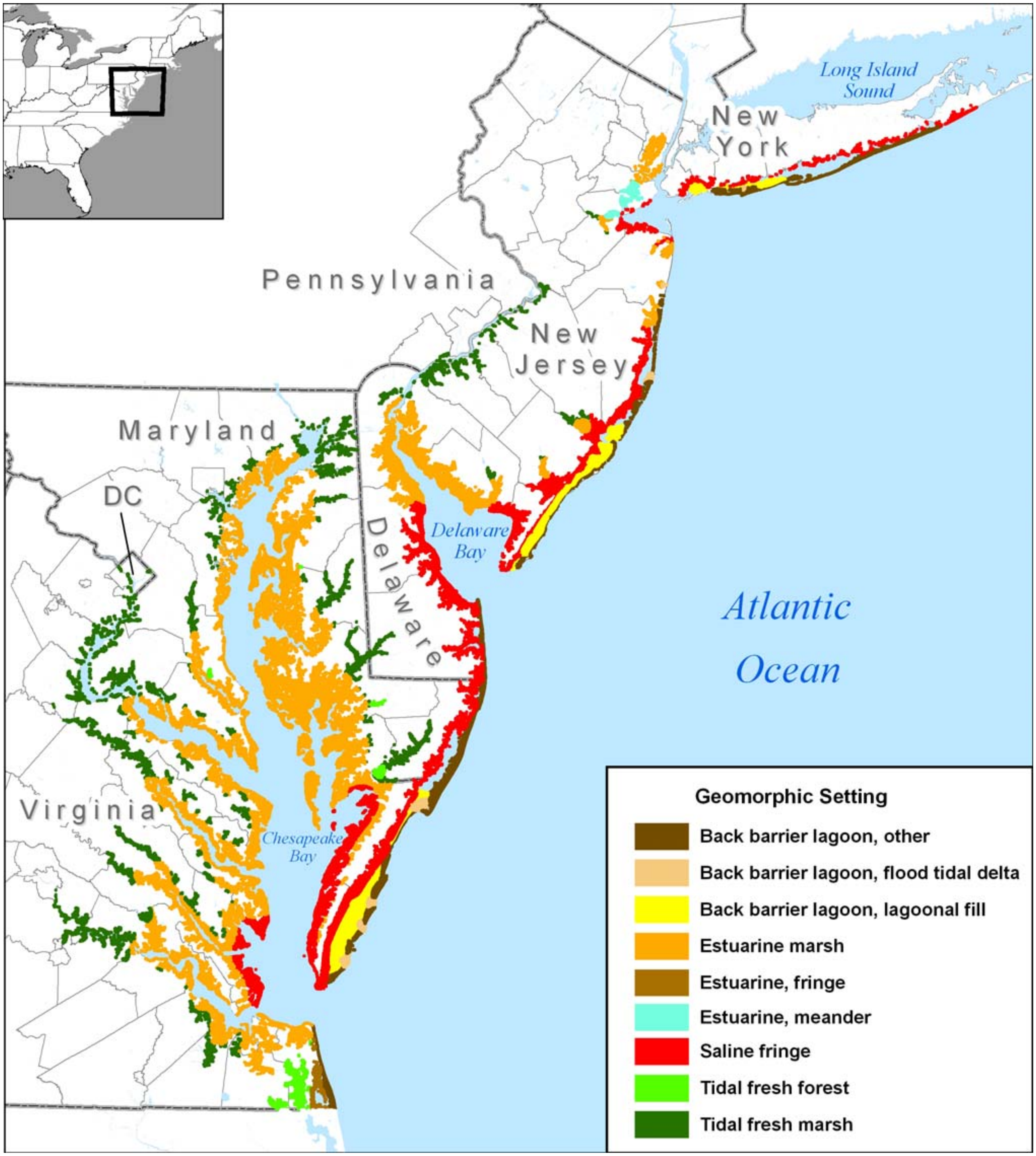
Figure 2.2.6. Legend for wetland accretion map.

Maps 2.2.1 and 2.2.2 provide the regional summary maps that we created based on the aforementioned considerations. Because the panel wanted to include subregional maps in the panel report, we also provided subregional maps. We do not reproduce those maps here but they are available with the data product EPA is distributing.[10] The consensus of panel members was that the accretion map is not valid at large scales. Therefore, the subregion-specific maps should not be reproduced without both a warning and an explanation about why the maps are being reproduced at this scale.[11]

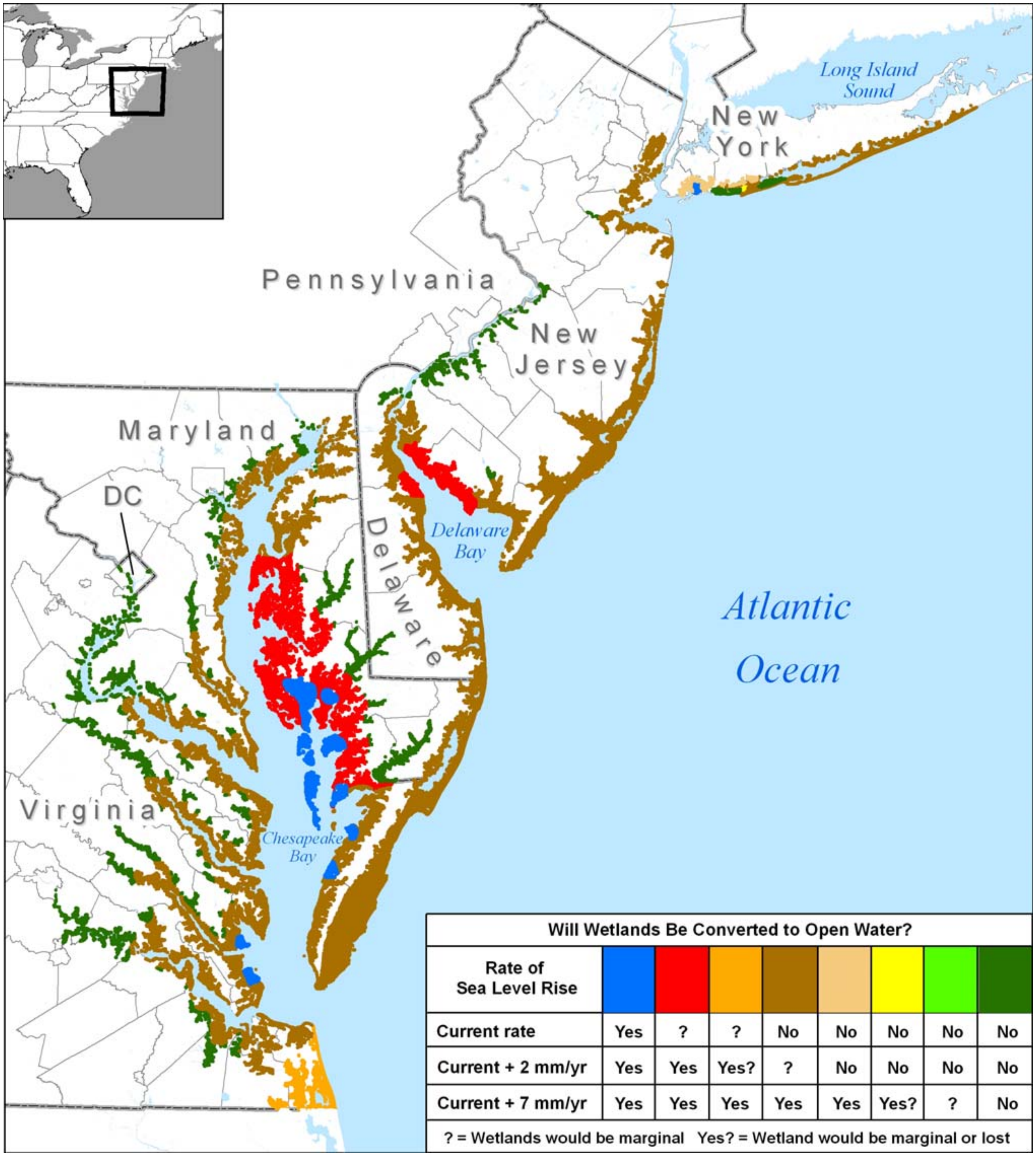
[9]For example, the polygon boundaries did not match—or the geomorphic setting was different—at a quadrangle boundary.

[10]Upon release of this report, EPA will make the data set described in this paper available to all researchers.

[11]Given the 1 cm errors in the hand renderings, National Map Accuracy standards would suggest a 1:5,000,000 scale.



Map 2.2.1. Geomorphic Setting of Tidal Wetlands: Montauk Point to Virginia Beach



Will Wetlands Be Converted to Open Water?								
Rate of Sea Level Rise	(blue)	(red)	(orange)	(brown)	(tan)	(yellow)	(light green)	(dark green)
Current rate	Yes	?	?	No	No	No	No	No
Current + 2 mm/yr	Yes	Yes	Yes?	?	No	No	No	No
Current + 7 mm/yr	Yes	Yes	Yes	Yes	Yes	Yes?	?	No

? = Wetlands would be marginal Yes? = Wetland would be marginal or lost

Map 2.2.2 Potential for Tidal Wetland Accretion in the Mid-Atlantic: Montauk Point to Virginia Beach.