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DIGITAL WATERSHED AND BAY BOUNDARIES FOR REHOBOTH BAY, INDIAN RIVER BAY, AND INDIAN RIVER

By

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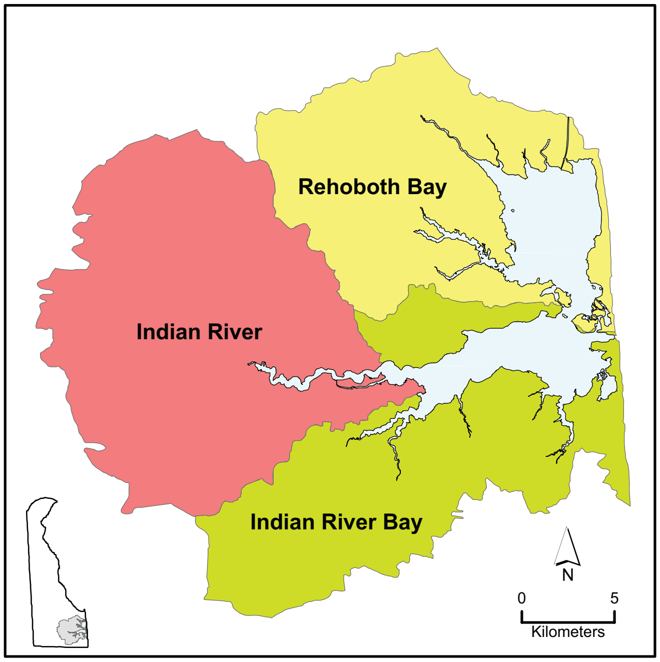

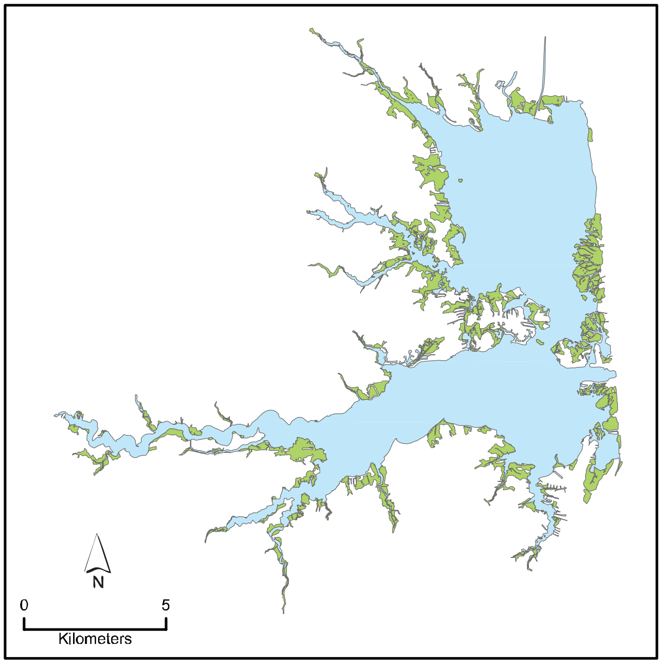

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DIGITAL WATERSHED AND BAY BOUNDARIES FOR REHOBOTH BAY, INDIAN RIVER BAY, AND INDIAN RIVER

Thomas E. McKenna, A. Scott Andres, and Kerrilynn P. Lepp

ABSTRACT

Digital watershed and bay polygons for use in geographic information systems were created for Rehoboth Bay, Indian River, and Indian River Bay in southeastern Delaware. Polygons were created using a hierarchical classification scheme and a consistent, documented methodology that enables unambiguous calculations of watershed and bay surface areas within a geographic information system. The watershed boundaries were delineated on 1:24,000-scale topographic maps. The resultant polygons represent the entire watersheds for these water bodies, with four hierarchical levels based on surface area. Bay boundaries were delineated by adding attributes to existing polygons representing water and marsh in U.S. Geological Survey Digital Line Graphs of 1:24,000-scale topographic maps and by dissolving the boundaries between polygons with similar attributes. The hierarchy of bays incorporates three different definitions of the coastline: the boundary between open water and land, a simplified version of that boundary, and the upland-lowland boundary. The polygon layers are supplied in a geodatabase format.

INTRODUCTION

Because surface areas of watersheds and water bodies are fundamental parameters used in many environmental studies, they require definition and delineation of their boundaries. Watershed managers and regulators often rely on results of this environmental research, and some regulations only apply within the boundaries of specific watersheds. For example, researchers determine the theoretical amount, frequency, and duration of contaminant loading that a water body can assimilate before it becomes impaired relative to some water quality standard (Total Maximum Daily Load (TMDL); Environmental Protection Agency EPA, 1991). These TMDL determinations rely on watershed delineations and calculations of their surface areas to quantify contaminant inputs and loads. In addition, inter-watershed comparisons are often made using the loads per unit areas of watersheds to aid in characterizing sources and pathways of contaminants. Subsequently, researchers may work with natural-resource managers to develop strategies to reduce the actual contaminant load to a particular watershed to meet its TMDL level. While surface area of watershed is only one of many parameters (e.g. precipitation, land use and land cover, contaminant concentration) that go into these types of calculations, all parameters have some level of associated uncertainty. In the given example, explicitly acknowledging and analyzing the uncertainty of all parameters is recognized as a critical aspect in the scientific approach (National Research Council (NRC), 2001). This requires documentation of methods used to estimate all parameters, including surface area.

Purpose and Scope

The purpose of this report is to provide a set of digital watershed boundaries and coastlines for the Inland Bays at a scale of 1:24,000 that encompass the entire watershed. Sets of watershed and bay boundaries were delineated for Rehoboth Bay (RB), Indian River (IR), and Indian River Bay (IRB) in southeastern Delaware (Fig. 1). A hierarchical classification scheme enables unambiguous calculations of watershed and bay surface areas within a geographic information system (GIS). Although Delaware's Inland Bays consist of these three water bodies and Little Assawoman Bay, the term "Inland Bays" refers only to RB, IRB, and IR, in this document. The digital boundaries were created using a consistent methodology to enable reproducible, quantitative spatial analyses of environmental variables within the Inland Bays watershed and in the Inland Bays. Four sets of watersheds are classified by surface area and are included as layers in the distribution. The distribution includes several different boundary definitions between the watersheds and the bays or adjacent marsh (herein called "coastlines"). Methods are given for customizing watershed and bay boundaries by modifying attribute values for existing polygons and clipping watershed polygons with bay polygons. All digital files associated with this report are accessible through the Delaware Geological Survey (DGS) Data Repository under "Publications" at http://www.udel.edu/dgs.

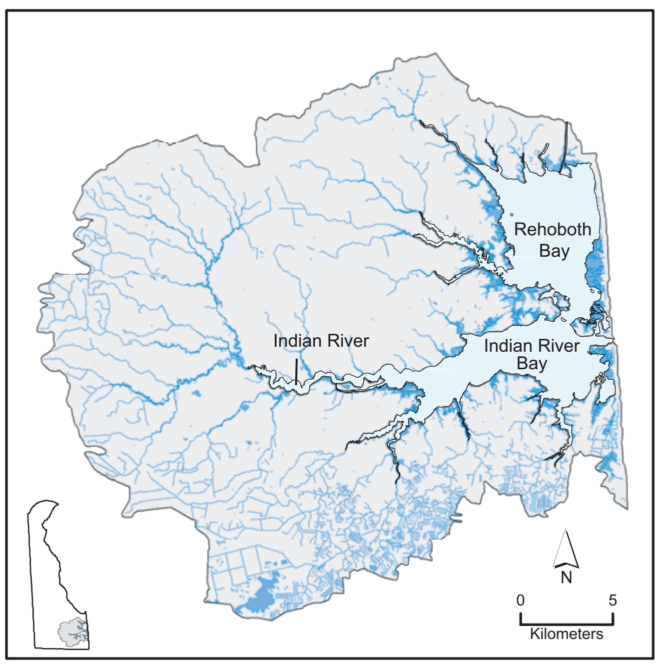

Figure 1. Location of Inland Bays watershed.

Previous Work

Other watershed delineations are available for all or part of the Inland Bays watershed and were consulted while preparing this dataset. The watersheds in this dataset cover the entire Inland Bays watershed, are based on hydrologic boundary conditions at their downstream ends, incorporate a coastline coincident to coastlines on published topographic maps, and are appropriate for use at map scales as large as 1:24,000. These delineations are modifications of delineations by Mackenzie et al. (1999) that utilized an automated technique with subsequent manual editing to gain "general consistency" with natural streams on 1:100,000 scale maps. Watersheds delineated by Steeves and Nebert (1994), Mackenzie et al. (1999), Delaware's Department of Natural Resources and Environmental Control (DNREC, 2001), Gutierrez-Magness and Raffensperger (2003), and Mark Nardi (USGS, 2005, personal communication) also cover the entire watershed. The Gutierrez-Magness and Raffensperger (2003) and Nardi (2005, personal communication) delineations also used the Mackenzie et al. (1999) delineations as a starting point for delineating watershed boundaries. Gutierrez-Magness and Raffensperger (2003) modified the delineations to factor in both locations of impaired stream segments and sampling points and to be consistent with other DNREC-supplied data. At this point, no specific information on watershed delineations is available to help users further evaluate appropriate uses of the DNREC (2001) and Nardi (USGS, 2005, personal communication) data. Steeves and Nebert (1994) delineated watersheds appropriate for use at a much smaller map scale of 1:250,000. Because Doheny (1998), Talley and Simmons (1988), and Ullman et al. (2002) delineated watersheds behind selected stream gages, they do not cover the entire Inland Bays watershed.

Acknowledgments

Early versions of the digital layers were created to support a project entitled "CISNet: Nutrient Inputs as a Stressor and Net Nutrient Flux as an Indicator of Stress Response in Delaware's Inland Bays Ecosystem" (EPA Star Grant R826945). Lillian T. Wang (DGS) prepared the figures.

METHODS

Two fundamental GIS layers were created as the basis of the hierarchy. First, a watershed layer (InlandBaysWatershedSmall; Fig. 2) stores the boundaries between watersheds. Second, a bay layer (BayRawDLG; Fig. 3) stores the boundary between watersheds and the bays (coastline) as polygons representing the bays. Different methods were used to create the fundamental layers. Boundaries between watersheds were delineated based on topographic and hydrologic characteristics discerned from the topographic maps as well as on the authors' knowledge of altered drainage patterns. These boundaries were delineated on digital versions of published

Table 1. U.S. Geological Survey (USGS) topographic maps (1:24,000) used for delineation of watershed boundaries. All maps have 5-foot topographic contour intervals.

USGS Quadrangle	Publication Date
Bethany Beach	1984
Fairmount	1992
Frankford	1984
Georgetown	1992
Harbeson	1992
Millsboro	1992
Rehoboth Beach	1984
Selbyville	1992
Trap Pond	1992
Whaleysville	1992

Figure 2. Small watersheds layer ("InlandBaysWatershedSmall" – fundamental watershed layer). Acronyms are defined in Table 2.

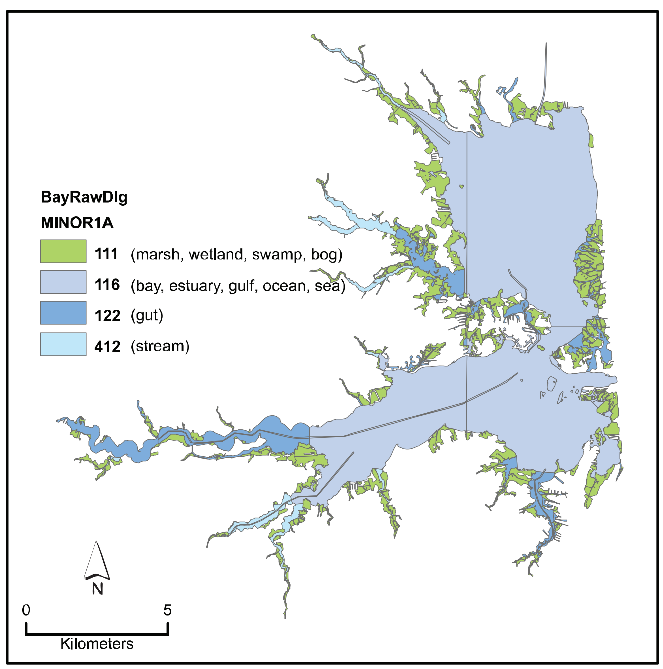

Figure 3. Bay layer with all DLG polygons ("BayRawDLG" – fundamental bay layer).

1:24,000-scale topographic maps having 5-foot topographic contour intervals (Table 1). Boundaries initially created by an automated process (Mackenzie et al., 1999) were then manually edited. Boundaries between watersheds and the bays were created by selecting polygons with specific attribute values from existing representations of the 1:24,000-scale topographic maps (i.e. Digital Line Graphs [DLGs]). All other watersheds and bay layers in the dataset were created from these fundamental layers using the standard GIS function to dissolve boundaries between polygons with equivalent attribute values.

U.S. Natural Resources Conservation Service (NRCS) guidelines (NRCS, 1997) were followed to produce the boundaries between watersheds with the exception that very little field checking was done to check boundary locations. Unique watershed delineations are difficult in areas of low topographic relief such as the Inland Bays watershed and especially in the southern part of the watershed where ditching is ubiquitous. In areas where a clear watershed boundary definition was not possible (mostly ditches and low-lying areas south of Indian River), a generalized boundary was drawn as recommended by the NRCS (1997) guidelines. Details about the procedures used to create the boundaries are given in Appendix A.

Coastlines are represented as the landward boundaries of polygons defining the area of the Inland Bays, and several representations of this boundary are available in the dataset. Three "coastlines" were defined as alternative boundaries between the watersheds and the bays:

i) "open water" - a coastline around all open water of the Inland Bays (see definition below),
ii) "simplified open water" - a simplified coastline that has minor asperities removed from the "open water" coastline, and
iii) "open water and marsh" - a coastline that includes all open water of the Inland Bays and all adjacent marsh (see definition below).

"Open water" of the bays is defined herein as all water represented with water polygons in the 1:24,000 DLGs that are adjacent to other water polygons in a series that includes the polygon representing the middle of the bay. The U.S. Geological Survey (USGS) National Mapping Division (Shannon Bain, USGS, 2001, personal communication) generally designates any water body wider than approximately 15.2 m (50 feet; .025" or 1/40th inch at 1:24,000 scale) as a polygon in a DLG; smaller water bodies are defined as lines. "Marsh" is defined herein as all marsh represented with marsh polygons in the DLGs that are adjacent to other marsh or "open water" polygons in a series that includes the polygon representing the middle of the bay. Details on the procedures used to create the boundaries are given in Appendix B.

RESULTS AND DISCUSSION

Four sets of watersheds and five sets of bay polygons are included in the distribution as feature classes in a geodatabase. The layers are appropriate for use at scales as large as 1:24,000. The four sets of watersheds represent an hierarchy based on surface area and are named InlandBaysWatershedSmall (fundamental layer), InlandBaysWatershedIntermediate, InlandBaysWatershedLarge, and InlandBaysWatershedSingle. Three sets of bay polygons incorporate three different definitions of the coastline and are named BayOpenWaterSimplified_level_1 (a simplified version of the boundary between open water and land, BayOpenWater_

Table 2. Watersheds arranged in hierarchical order.

Watershed Set				
Single	***Large***	*Intermediate*	Small	Small Acronym
Inland Bays				
	Rehoboth Bay			
		Rehoboth Bay north & east		
			Delaware Seashore North	DSN
			Lewes & Rehoboth Canal	LRC
			White Oak Creek	WOC
		Love Creek		
			Arnell Creek	ARN
			Angola Neck	ANG
			Love Creek, lower	LCL
			Love Creek	LOV
			Bundicks Brach	BUN
		Herring Creek		
			Herring Creek North	HCN
			Sarah Run	SAR
			Chapel Branch	CHA
			Herring Creek South	HCS
			Unity Branch	UNI
			Phillips Branch	PHI
			Guinea Creek	GUI
			Guinea Creek Upper	GUU
			Long Neck North	LNN
	Indian River			
		Indian River north & Swan Creek		
			Warwick Gut	WAG
			Swan Creek, lower	SWL
			Swan Creek	SWA
			Indian River North	IRN
		Millsboro Pond northwest		
			Millsboro Pond northwest	MPN
		Millsboro Pond southwest		
			Millsboro Pond southwest	MPS
		Indian River south & Iron Branch		
			Indian River South	IRS
			Iron Branch	IRO
			Whartons Branch	WHA
			Piney Neck North	PNN
	Indian River Bay			
		Indian River Bay north		
			Long Neck South	LNS
			Oak Orchard	OAK
		Pepper Creek		
			Pepper Creek lower	PCL
			Pepper Creek	PEP
		Vines Creek		
			Vines Creek, lower	VCL
			Vines Creek	VIN
		Indian River Bay south & east		
			Blackwater Creek, lower	BCL
			Blackwater Creek	BLA
			Holts Landing	HOL
			White Creek	WHI
			Salt Pond	SAL
			Delaware Seashore South	DSS

level_2 the boundary between open water and land), and BayOpenWaterAndMarsh_level_3 (the upland-lowland boundary). BayRawDLG (fundamental bay layer) includes all of the DLG polygons. The set of bay polygons named BayAllPolygons_level_0 has boundaries between DLG polygons having equivalent MINOR1A codes (bay, gut, stream, marsh) removed.

Using the simplified coastline for the boundaries between the watersheds and bay, a hierarchy of watershed delineations is provided (Table 2) that includes a single watershed for the entire Inland Bays watershed (Fig. 1) and sets of large, intermediate, and small watersheds (Table 3). The single watershed (Fig. 1) has an area of approximately 592 km^2, consistent with NRCS guidelines for 11-digit watersheds or equivalently what NRCS calls "watersheds" (NRCS, 1997). Three large watersheds (Fig. 4, Table 4) with surface areas similar to DNREC-defined watersheds (DNREC, 2001) were delineated with areas of 159, 178 and 254 km^2 (also within NRCS specifications for 11-digit watersheds). Eleven intermediate watersheds were delineated with areas consistent in size with specifications for

Table 3. Summary statistics for watershed surface areas.

Set	Number	*Area (km^2) mean	minimum	maximum
Single	1	592	-	-
Large	3	197	159	254
Intermediate	11	53.8	19.6	85.7
Small	39	15.2	2.29	85.7

* Area calculated using the simplified open water coastline. Area does not include open bay waters, but does include any water features landward of coastline (e.g. ponds,streams). Areas presented with three significant digits so total may not match sum of areas in other tables.

Table 4. Surface areas of large watersheds.

Watershed	*Area (km^2)
Rehoboth Bay	159
Indian River	254
Indian River Bay	178

* Area calculated using the simplified open water coastline. Area does not include open bay waters, but does include any water features landward of coastline (e.g. ponds,streams).

Table 5. Surface areas of intermediate watersheds (large watershed names in bold font).

Watershed	*Area (km^2)
Rehoboth Bay	
Rehoboth Bay north & east	19.6
Love Creek	56.6
Herring Creek	83.3
Indian River	
Indian River north & Swan Creek	36.0
Millsboro Pond northwest	85.7
Millsboro Pond southwest	74.0
Indian River Bay	
Indian River south & Iron Branch	58.3
Indian River Bay north	22.9
Pepper Creek	34.1
Vines Creek	62.3
Indian River Bay south & east	59.1

* Area calculated using the simplified open water coastline. Area does not include open bay waters, but does include any water features landward of coastline (e.g. ponds,streams).

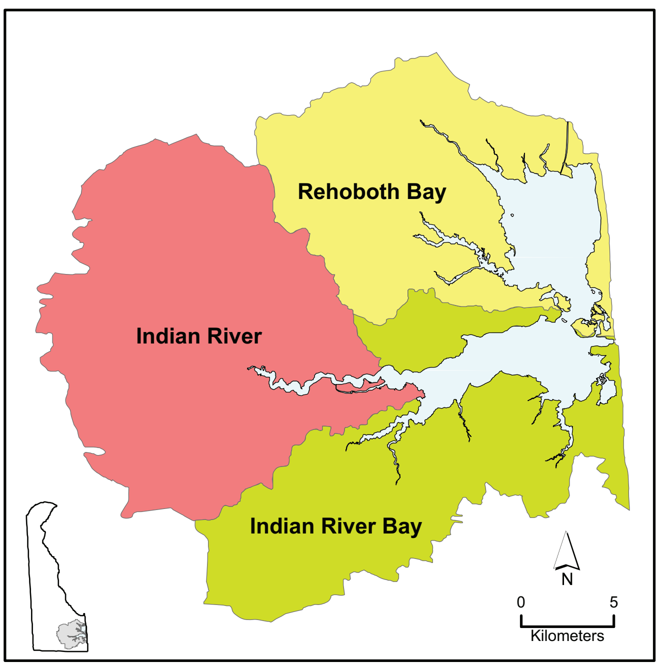

Figure 4. Large watersheds layer ("InlandBaysWatershedLarge").

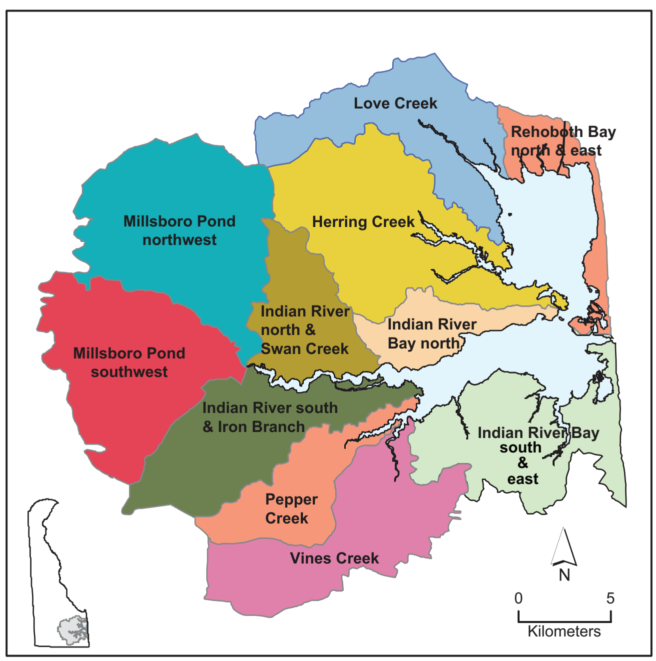

Figure 5. Intermediate watersheds layer ("InlandBaysWatershed Intermediate").

Table 6. Surface areas of small watersheds (intermediate watershed names in bold font).

Watershed	*Area (km^2)
Rehoboth Bay north & east	
Delaware Seashore North (DSN)	7.11
Lewes & Rehoboth Canal (LRC)	6.46
White Oak Creek (WOC)	6.08
Love Creek	
Arnell Creek (ARN)	6.94
Angola Neck (ANG)	8.78
Love Creek, lower (LCL)	11.1
Love Creek (LOV)	9.73
Bundicks Branch (BUN)	20.0
Herring Creek	
Herring Creek North (HCN)	6.90
Sarah Run (SAR)	5.16
Chapel Branch (CHA)	22.3
Herring Creek South (HCS)	3.93
Unity Branch (UNI)	11.5
Phillips Branch (PHI)	6.85
Guinea Creek (GUI)	4.60
Guinea Creek Upper (GUU)	14.7
Long Neck North (LNN)	7.30
Indian River north & Swan Creek	
Warwick Gut (WAG)	8.42
Swan Creek, lower (SWL)	12.8
Swan Creek (SWA)	12.1
Indian River North (IRN)	2.73
Millsboro Pond northwest	
Millsboro Pond northwest (MPN)	85.7
Millsboro Pond southwest	
Millsboro Pond Southwest (MPS)	74.0
Indian River south & Iron Branch	
Indian River South (IRS)	5.49
Iron Branch (IRO)	25.8
Whartons Branch (WHA)	15.8
Piney Neck North (PNN)	11.1
Indian River Bay north	
Long Neck South (LNS)	11.2
Oak Orchard (OAK)	11.7
Pepper Creek	
Pepper Creek lower (PCL)	11.9
Pepper Creek (PEP)	22.3
Vines Creek	
Vines Creek, lower (VCL)	16.4
Vines Creek (VIN)	37.0
Indian River Bay south & east	
Blackwater Creek, lower (BCL)	19.6
Blackwater Creek (BLA)	8.97
Holts Landing (HOL)	10.6
White Creek (WHI)	18.9
Salt Pond (SAL)	7.65
Delaware Seashore South (DSS)	2.29

* Area calculated using the simplified open water coastline. Area does not include open bay waters, but does include any water features landward of coastline (e.g. ponds,streams).

NRCS "subwatersheds" (14-digit watersheds) with areas ranging from 19.6 to 85.7 km^2 and a mean size of 53.8 km^2 (Fig. 5, Table 5). Thirty-nine small watersheds were delineated with areas ranging from 2.29 to 85.7 km^2 and a mean size of 15.2 km^2 (Fig. 2, Table 6) and have no equivalent NRCS designation.

The delineations are necessarily subjective but they are consistent with the topographic contours on published 1:24,000-scale USGS topographic maps except where the authors had other knowledge of altered drainage patterns (primarily along roadways). The data are supplied in the Universal Transverse Mercator projection and coordinate system (UTM Zone 18N) based on the 1983 North American Datum (NAD83) and units of meters are used. Area calculations for watersheds and bay (Table 7) were done using the same projection. Comparisons between area calculations using the UTM 18 projection and other equal-area projections resulted in insignificant differences in area of < 0.01 percent.

Table 7. Surface areas of bay.

Level*	Description	Bay Area (km^2)
1	Simplified Open Water	76.4
2	Open Water	79.4
3	Open Water and Marsh	98.0

* Level refers to attribute name in bay layers (e.g. LEVEL_1).

User Customization

Because the clipping operation will create smaller watersheds that are subsets of the supplied watersheds, users can clip any of the supplied watersheds with any of the bay polygons (using the "ERASE" function in ArcGIS) without ambiguity in the resulting watershed/bay boundaries.

Users can create custom watershed definitions from the existing polygons by populating the DISSOLVE attribute in the fundamental watershed layer with their own values and dissolving polygon boundaries between polygons with equivalent values for the DISSOLVE attribute.

Distribution and Use

The digital layers are available for downloading from the DGS Data Repository under "Publications" at http://www.udel.edu/dgs as a file named InlandBays Watershed24K.zip. The geodatabase is named "InlandBays Watershed24K.mdb" and is in the ESRI personal geodatabase format compatible with ESRI ArcGIS products. In addition, ArcMap "layer" files are included in the distribution and can be used in ArcGIS to automatically color symbolize features in the layers. Metadata are included for each feature class.

CONCLUSIONS

Digital watershed and bay polygons were created using a hierarchical classification scheme for Rehoboth Bay, Indian River, and Indian River Bay in southeastern Delaware. The polygon layers are supplied in a geodatabase format and are appropriate for use at 1:24,000-scale or smaller. The layers enable unambiguous calculations of watershed and bay surface areas within a GIS.

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Appendix A: Procedure Used to Create Boundaries Between Watersheds

Fundamental Layer for Boundaries Between Watersheds (InlandBaysWatershedSmall)

The watershed boundaries were created using the following procedure:

1. Watershed boundaries were retrieved from the website of the Spatial Analysis Laboratory (SPATLAB) at the University of Delaware (Mackenzie et al., 1999). Mackenzie et al. (1999) utilized an automated technique within the open-source GIS software (GRASS) to delineate the watersheds. Manual correction (on-screen digitizing) of boundaries for general consistency with 1995 TIGER hydrography data from the U.S. Census Bureau (based on 1:100,000-scale USGS topographic maps) was done by SPATLAB personnel to ensure watershed boundaries only crossed natural streams at their downstream limit (spillpoint).

2. Files were imported into ESRI's ArcGIS software and converted from a raster to vector format, and boundaries were smoothed using the GENERALIZE and SPLINE functions in ArcGIS. Some boundaries not used in the hierarchy were removed.

3. Manual editing (on-screen digitizing) of boundaries was done at a scale of 1:12,000 or greater to ensure consistency with streams and topographic boundaries on the 1:24,000 USGS Digital Raster Graphics [DRG] and DLG. When there were irreconcilable discrepancies between streams or contour lines on the DRG versus the DLG, the DRG feature was assumed to be in the correct location. During editing, all boundary lines were extended into the bay to facilitate later clipping by a polygon representing the coastline. Edits were guided by overlay and/or review of existing digital datasets and/or paper maps (DNREC, 2001; Doheny, 1998; Gutierrez-Magness and Raffensperger, 2003; Mackenzie et al., 1999; Steeves and Nebert, 1994; Talley and Simmons, 1988; and Ullman et al., 2002).

4. The feature class was named **InlandBays-WatershedSmall** (Fig. 2) and the attributes LARGE, INTERMEDIATE, and SMALL were added to assign watershed names to features. This is the fundamental layer (feature class) from which all other layers for watersheds were created. An attribute named DISSOLVE was added to allow users to create custom watersheds by dissolving boundaries between polygons with equivalent DISSOLVE attribute values.

5. InlandBaysWatershedSmall was clipped (using the ArcGIS "ERASE" command) by the "simplified open water" polygon (BayOpenWater-Simplified_level_1) described below. Using this bay polygon for clipping InlandBaysWatershedSmall created the largest possible areas for all watersheds.

Derivatives of the Fundamental Watershed Layer

Feature classes named **InlandBaysWatershedLarge** (Fig. 4) and **InlandBaysWatershedIntermediate** (Fig. 5) were created by dissolving boundaries between polygons in InlandBaysWatershedSmall with equivalent LARGE and INTERMEDIATE attribute values, respectively. The feature class named InlandBaysWatershedSingle (Fig. 1) was created by dissolving all polygon boundaries in InlandBaysWatershedSmall. All derivative watersheds use the "simplified open water" polygon as the coastline.

Appendix B: Procedure Used to Create Boundaries Between Watersheds and Bays

Fundamental Layer for Boundaries Between Watersheds and Bays (BayRawDLG)

The boundaries between watersheds and bays (coastlines) are stored as polygons representing the bay and adjacent marsh. The polygons were created using the following procedure:

1. The USGS 1:24,000-scale DLGs for the topographic maps in Table 1 were used. Polygons with attribute MINOR1 = 111 (marsh, wetland, swamp, bog), 116 (bay, estuary, gulf, ocean, sea), 122 (gut), or 412 (stream) were extracted from the DLGs. All polygons not contiguous to the open waters of the Inland Bays were manually deleted. Some polygons with obvious errors in the MINOR1 attribute value were also removed. The MAJOR1, MAJOR2, MINOR1, and MINOR2 attributes from the original DLGs were preserved. All other DLG attributes were deleted.

2. A new attribute named MINOR1A was added to facilitate correction of errors in MINOR1 attribute values for 27 polygons, and an appropriate value was assigned to MINOR1A based on comparison with the DRGs. The values were modified in MINOR1A because MINOR1 had an invalid value of "0", a "no data" value of "-99999", a value that was not consistent with surrounding polygons (e.g. value represented as "bay" when all adjacent polygon values represented "gut" and land features), or a value typically used in the MINOR2 field (e.g. value represented "channel" rather than the MINOR1 code of the surrounding polygons representing "bay", "stream" or "gut'"). Some small polygons representing islands in open water were recoded in MINOR1A to represent "bay." Some small land and water polygons surrounded by marsh were recoded in MINOR1A to represent "marsh." Together, all of these recoded small polygons represent less than 0.1% of the total area.

3. The layer was named **BayRawDLG** (Fig. 3) and the attributes FLAG, FINAL_CODE, LEVEL_0, LEVEL_1, LEVEL_2, and LEVEL_3 were added and populated to facilitate polygon selection for dissolving of polygon boundaries to get different representations of a coastline. The FLAG attribute was created to enable culling of asperities in the coastline and values of zero (keep) or one (cull) were entered for each polygon. Polygons with small area to perimeter ratios (A:P) were selected for culling via visual inspection and assigned a FLAG value of "1" to facilitate creation of a simplified coastline. (The average A:P for culled polygons (14) was an order of magnitude smaller than the A:P of polygons kept (185) for the simplified coastline.) FINAL_CODE combines the FLAG value and the MINOR1A value into a code to enable creation of different representations of the coastline (referred to below as "coastline levels" or "levels"). Values for FINAL_CODE attributes (BF0, BF1, GSF0, GSF1, M) recode MINOR1A values into bay, marsh, or gut/stream descriptors (M =111, B=116, GS = 122 and 412) and FLAG values (F0=0 and F1=1). The LEVEL_0, LEVEL_1, LEVEL_2, and LEVEL_3 attribute values were populated based on the FINAL_CODE attribute values and desired output of the dissolve function. The distinct attribute values for each of the LEVEL attributes are:

LEVEL_0: B, G, S, M (bay, gut, stream, marsh)
LEVEL_1: BAY
LEVEL_2: BAY
LEVEL_3: BAY, MARSH

Derivatives of the Fundamental Layer for Boundaries Between Watersheds and Bays

The layers below were derived from the BayRawDLG layer by dissolving boundaries between polygons using the LEVEL_# attribute and selecting all polygons with non-NULL values for the LEVEL_# attribute. These feature classes can be used to clip the watershed polygons.

1. **BayAllPolygons_level_0** (Fig. 6) represents all open water of the bay and all marsh adjacent to the bay. Boundaries between polygons with equivalent LEVEL_0 values were dissolved resulting in four features each having multiple polygons. The differentiation of water types in the original DLG is preserved (bay, gut, stream, marsh).

2. **BayOpenWaterSimplified_level_1** (Fig. 7) represents a simplified coastline for open water. Boundaries between polygons with equivalent LEVEL_1 values were dissolved resulting in one feature with one polygon. Many high-frequency, landward-convex asperities in the coastline were identified manually and are not included in this dataset.

3. **BayOpenWater_level_2** (Fig. 8) represents all contiguous open water of the bays. Boundaries between polygons with equivalent LEVEL_2 values were dissolved resulting in one feature with one polygon.

4. **BayOpenWaterAndMarsh_level_3** (Fig. 9) represents all contiguous open water and marshes of the bays with the distinction between marshes and bay preserved as separate features. Boundaries between polygons with equivalent LEVEL_3 values were dissolved, resulting in one feature with a single polygon representing the open water of the bays and a second feature with multiple polygons representing adjacent marshes.

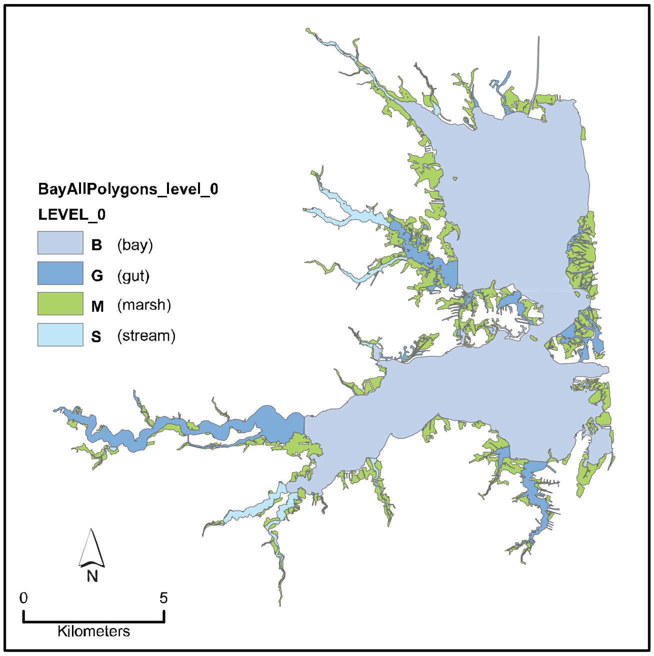

Figure 6. Bay layer with boundaries between DLG polygons having equivalent MINOR1A codes (bay, gut, marsh, stream) removed ("BayAllPolygons_level_0").

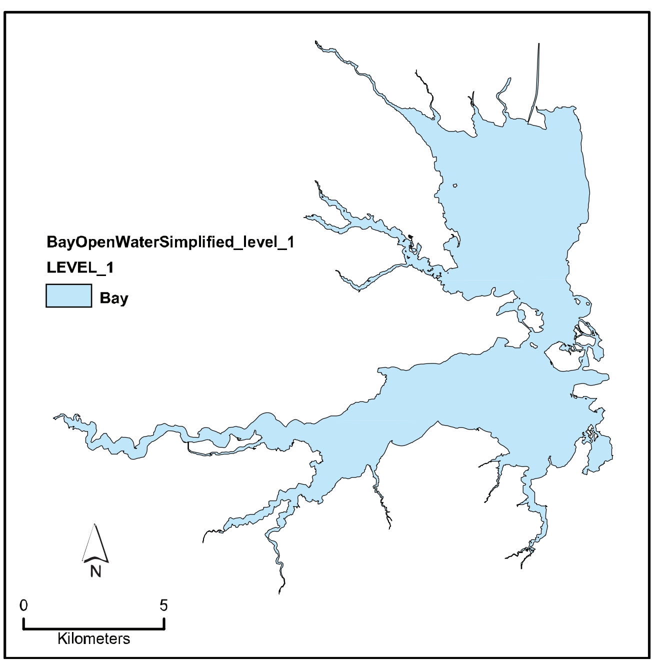

Figure 7. Bay layer with simplified open water coastline ("BayOpenWaterSimplified_level_1").

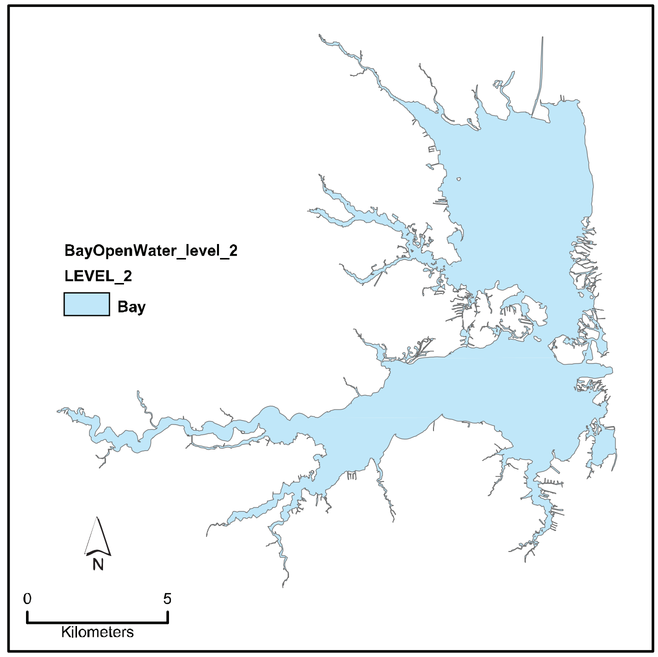

Figure 8. Bay layer with open water coastline ("BayOpenWater_level_2").

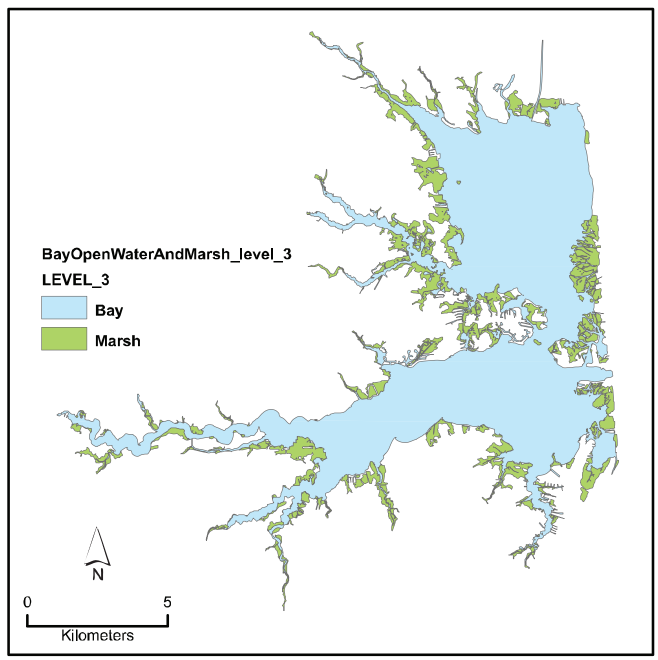

Figure 9. Bay layer with open water and marsh coastline ("BayOpenWaterAndMarsh_level_3").