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Introduction

Wetlands are known to be very valuable elements in a landscape. They provide a natural capacity to improve water quality, trap sediments, moderate floods, recharge groundwater supplies, provide habitat, and create aesthetic and recreational amenities.

The U.S. Fish and Wildlife Service's National Wetlands Inventory Program (NWI) recently completed all of the more than 800 maps required to cover Virginia. The NWI maps wetland type and location using high altitude aerial photography. Wetlands are identified by trained photointerpreters and recorded on United States Geologic Survey topographic quadrangles at a 1:24,000 scale.

Despite the intensive nature of the NWI mapping effort, it is still not a 100% accurate inventory of wetlands on the landscape. This is because some types of wetlands are extremely difficult to detect from aerial photographs. In general, small forested nontidal wetlands are most difficult to detect, and therefore, NWI maps are typically a conservative estimate of the number and extent of these wetlands in an area (National Wetlands Inventory, Stolt and Barker 1995, Bernert et al. 1999).

When mapping wetlands, NWI uses a classification system which identifies each wetland as one of four types: Estuarine, Lacustrine, Riverine, and Palustrine.

- *Estuarine wetlands* are those associated with tidal waters. In Virginia, these are the wetlands subject to the Tidal Wetlands Act implemented by the Virginia Marine Resources Commission and local wetlands boards.
- *Lacustrine wetlands* are those associated with lakes, generally in shallow waters around the periphery.
- *Riverine wetlands* are those found within the banks of rivers and streams.
- *Palustrine wetlands* include all nontidal wetlands on the landscape outside of lakes, rivers and streams. Palustrine wetlands include the riparian wetlands found next to rivers and lakes, and they include the isolated wetlands found away from any surface watercourses.

Based on the NWI maps of Virginia's wetland resource, there are approximately 1.2 millon acres of vegetated wetlands in the Commonwealth. Approximately 1 million of these acres are nontidal Palustrine wetlands (Table 1).

Isolated Wetlands

Isolated wetlands are wetlands that are not part of or adjacent to a surface tributary system of interstate or navigable waters of the United States. These wetlands are generally valued for both habitat and water quality functions. For instance, the ability to provide suitable wildlife habitat is an important function of isolated wetlands, and for some species of amphibians, separation from continuously inundated areas is essential (Semlitsch 1998, Semlitsch and Bodie 1998). Water quality functions are generally present due to ground water connections between isolated wetlands and surface waters (Winter 1988, Mitch and Gosselink 1993, National Resource Council 1995).

A Geographic Information System (GIS) analysis of the NWI maps for Virginia was undertaken to estimate the extent of isolated wetlands in the Commonwealth. The procedure is described in detail in Appendix I. The results of the GIS analysis suggest that there are approximately 93,000 acres of isolated wetlands or approximately 8% of the vegetated wetlands mapped by NWI in Virginia (Table 1).

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Headwater Wetlands

Headwater wetlands are wetlands of nontidal rivers, streams, and their lakes and impoundments that are part of a surface tributary system to an interstate or navigable waters of the United States upstream of the point on the river or stream at which the average annual flow is less than five cubic feet per second.

Headwater wetlands are located in the upper reaches of watersheds. These are wetlands that intercept and modify runoff and shallow groundwater entering streams that flow into the rivers and estuaries of the Commonwealth. They are considered particularly important for their potential role in water quality management. Most organic matter is introduced in waterways from upland sources in headwater areas. Organic matter is reduced in size by biological activity and travels downstream. Accordingly, headwater wetlands set the nutrient state of larger downstream systems and are the first step in treating water moving from the uplands to streams. Disturbance of headwater wetlands will affect water quality proportionately more than disturbance of wetlands further downstream (Peterjohn and Correll 1984, Cooper et al. 1987, Brinson 1993). Headwater wetlands also serve important roles in moderating storm runoff and providing habitat.

A GIS analysis of the NWI maps for Virginia was undertaken to estimate the extent of headwater wetlands in the Commonwealth. Since flow volumes are not available for most streams in Virginia, we have used stream order classification as a surrogate. Stream orders are determined (according to the Strahler method) by classifying the smallest perennial streams as first order streams. Where two first order streams combine, a second order stream is created, and so on through higher orders as streams and rivers flow to the ocean. After reviewing stream order maps for Virginia, we concluded that first and second order streams were most likely to be at or below the 5 cubic foot per second criterion. The detailed GIS procedure is described in Appendix I. The results of the GIS analysis suggest that there are approximately 387,450 acres of vegetated nontidal wetlands associated with first order streams in the Commonwealth. There are an additional 128,086 acres associated with second order streams. Collectively this represents approximately 43% of all the NWI mapped vegetated wetlands in Virginia (Table 2).

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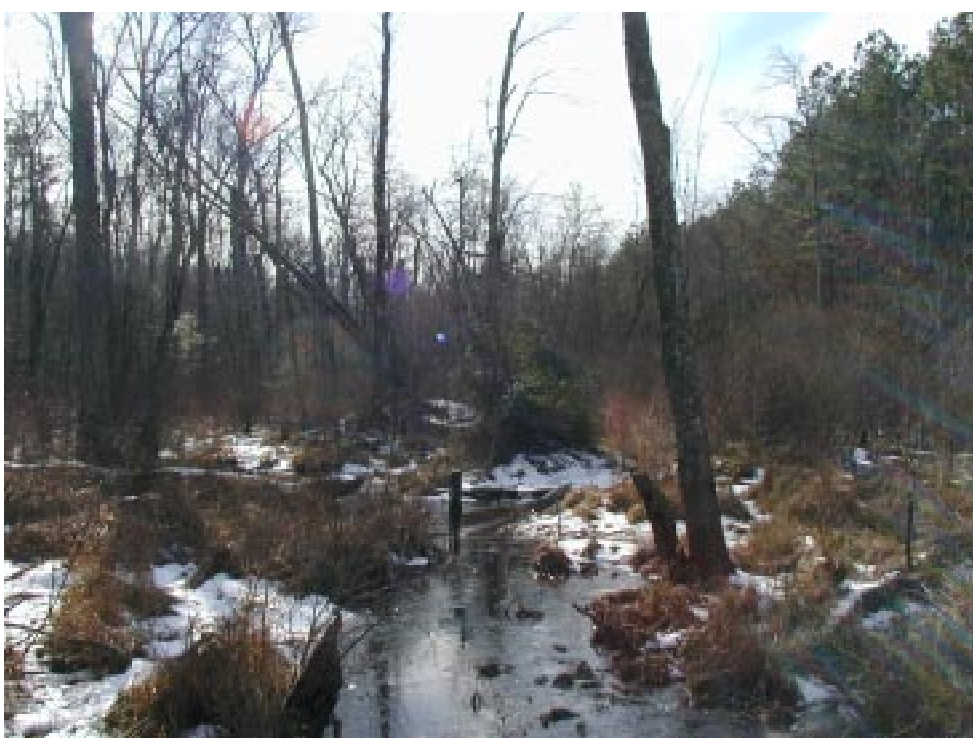


Isolated Palustrine forested wetland.

Appendix I

Analytical Protocols for Determining the Distribution and Abundance of Isolated and Headwater Wetlands in Virginia

Introduction

The following two analyses were performed to calculate isolated and headwater wetlands within Virginia. Analyses were performed using ESRI's ArcInfo® geographic information system (GIS) software. Specific protocols were required to analyze available GIS data. These protocols were based on an understanding of wetlands, hydrogeomorphic processes, and spatial data interpretation. Most procedures are written in Arc Macro Language (AML) code, Arc/Info's native programming language. Processing was done on a Unix Sun Ultra 10 workstation and a desktop PC with a Pentium 4 processor.

Procedure for Calculating Isolated Wetlands

The distribution and abundance of isolated palustrine wetlands in Virginia was computed using Geographic Information Systems (GIS) and available statewide GIS data. For this analysis, an isolated wetland is defined as any wetland that does not have a direct or indirect connection to surface hydrography. A wetland with an indirect connection is defined as a wetland contiguous to another wetland(s) intersected by surface hydrography.

The analysis integrates two principal datasets. First, digital National Wetlands Inventory (NWI) data at 1:24,000 scale delineates boundaries of all wetlands. Second, hydrography data creates the surface water stream network. The newest National Hydrography Dataset (NHD), available for 75% of the state, and Digital Line Graph (DLG) hydrography data were combined to generate the best statewide stream network possible. Both datasets are published at 1:24,000 scale. The NHD data, distributed in 8-digit hydrographic cataloging units, were appended into hydrographic drainages using the append tool provided on the NHD web site. Selecting from the NHD attribute list, the hydrography network for this analysis was compiled to include only arc FTYPE items equal to stream/river or canal/ditch, and polygons coded lake/pond, reservoir, stream/river, playa, canal/ditch, or sea/ocean. Selected items were converted to shape file format. Shape files were converted to ArcInfo coverages and projected in UTM zone 18/NAD 83.

DLG data was substituted for areas where NHD is not available. DLG data is distributed in SDTS (Spatial Data Transfer System) format in 1:24,000 scale quadrangles. Each quadrangle was converted to an ArcInfo coverage. These were then appended into one coverage. From the DLG attributes, arcs coded as closure line, processing line, shoreline, apparent limit, or "outline of a Carolina Bay" were excluded from the surface water network coverage. DLG polygons coded as marsh, wetland, flats, or sounding datum were also excluded.

A seamless NWI coverage was generated by appending and edgematching 816 quadrangles downloaded from the United States Fish and Wildlife Service's (USFWS) NWI web site. The most recent compilation of datasets as of October, 2002 were used. As this report was prepared no additional data were released. NWI data were spatially clipped for analysis to the boundaries of 17 different drainage areas.

The isolated wetland analysis includes four main steps. The first step dissolves shared boundaries between contiguous wetlands by assigning a new item to the wetland coverage, and coding all "wetlands" a value=1, and "uplands" a value=0.

The "DISSOLVE" command removes shared boundaries between all polygons with the same value. Linear wetlands (arcs) from the NWI coverage were buffered by 2m/side to create polygons. These were also recoded and dissolved in the same manner. A final dissolved wetland coverage combines the dissolved original polygonal wetlands with the dissolved linear wetlands.

The second step develops a surface water network coverage for each drainage area; 17 drainage areas in all. Thirteen drainage areas are derived from NHD, three are DLG based and one is a mix of NHD and DLG. They include arcs and polygons. All arcs and polygons are buffered 2m to account for some mapping errors inherent in the datasets. Where polygon buffers (e.g buffers around lakes) overlap arc buffers (e.g. buffers around streams) the "UNION" command is used to join them. The "DISSOLVE" command removes shared boundaries to form one interconnected surface water network.

The third step searches for wetlands that do not overlap the surface water network. This step overlays the wetland and surface water coverages. Any wetland intersected by hydrography is tagged with a new item named "adjacent". Wetlands not designated "adjacent" are coded "isolated". At this time, however, the type of wetland can not be distinguished.

The fourth step in the analysis restores original NWI attributes to the final coverage so a wetland's type (e.g. PEM, PFO) can again be determined from the dataset. This information was lost when the boundaries between individual polygons were dissolved. To restore this information to the attribute tables, the dissolved NWI coverage was unioned with the original NWI coverages clipped for drainage areas.

Finally, the distribution (acres) of isolated vegetated palustrine wetlands (palustrine emergent, palustrine forested, palustrine shrub-scrub) were computed on the basis of drainage area (Table 1). The area of all linear wetlands is computed based on the arc length multiplied by a constant = 5 meters.

Procedure for Calculating Headwater Wetlands

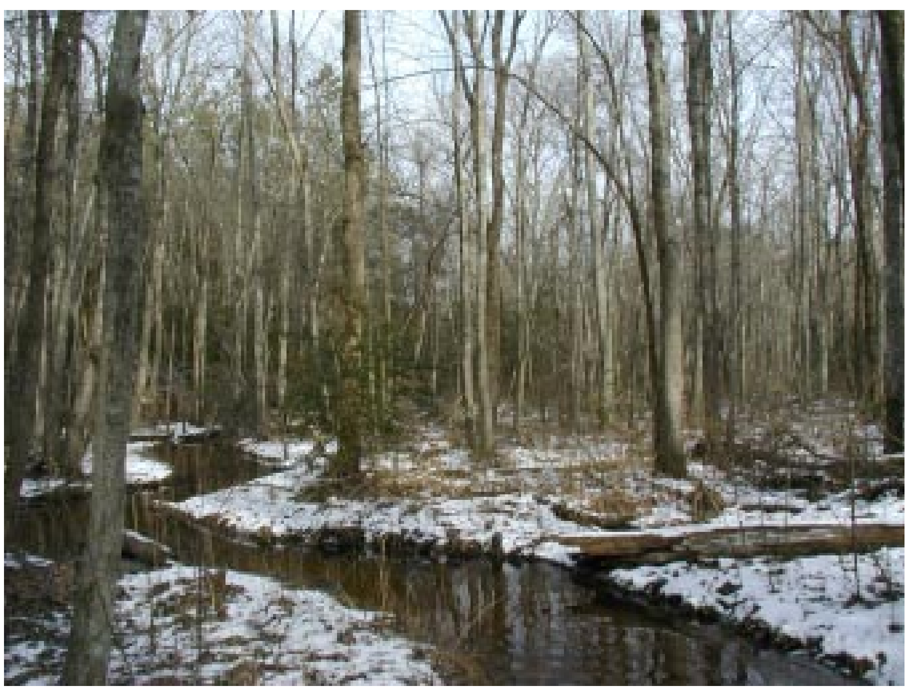
The objectives of this procedure were to identify and compute the abundance of headwater wetlands in Virginia. For this analysis, headwater wetlands are defined as any wetland that is intersected by first or second order streams only. The Environmental Protection Agency's (EPA) digital RF3 stream network was applied in this procedure. RF3 data uses the Strahler stream order classification system. The NWI data were used for wetland boundaries. The analysis was performed on data clipped to the 1:250,000 scale USGS block boundaries.

Both polygonal and linear wetlands were used. Linear wetlands were not buffered in this analysis. From the statewide coverage of NWI data, only the following classes were considered in this analysis: PFO, PEM, PSS, R*EM, and L2EM*, where * can be any character or set of characters. All other wetland areas were eliminated from consideration. Step one in this analysis uses the "SELECT" command to extract wetland polygons and arcs that belong only to these selected types.

Step two eliminates all wetlands (polygons and arcs) associated with high order streams (stream order ≥3). As a rule in this analysis, if a wetland is intersected by multiple streams of different orders, the wetland is assigned to the higher order stream. The "RESELECT" command with the "OVERLAP" option is used to eliminate a wetland intersected by a first order stream and a third order stream. The "DISSOLVE" command allows clusters of polygons to be analyzed as a single unit. If a cluster of contiguous wetland polygons intersect a high order stream at any point, all individual wetlands in that cluster are eliminated. The "RESELECT" command with the "OVERLAP" option is used again to determine if individual members of the clusters are intersected by headwater streams. If so, those polygons will remain in the analysis.

The remaining wetland polygons are coded as either a first order headwater wetland or a second order headwater wetland. Again, the “RESELECT” command with the “OVERLAP” option is used to determine intersection. If a wetland is intersected by both first and second order streams, the polygon is coded a second order headwater wetland. In addition, if a cluster of contiguous wetlands intersect a first or second order stream, all individual wetland polygons in the cluster are considered headwater wetlands and are assigned to the order of the intersecting stream. However, if a cluster of contiguous wetlands intersect both a first and second order stream, all wetlands in the cluster are assigned to second order, except for the individual wetland that directly intersects the first order stream. This individual member will be coded a first order headwater wetland.

Linear wetlands were also classified as headwater wetlands if they intersect first or second order streams also. A first order linear headwater wetland is one that intersects with a first order stream. A second order linear headwater wetland is a wetland intersected by a second order stream or by both first and second order streams.



Headwater Palustrine forested wetland.

Table 1. Isolated Wetlands in Virginia

Drainage	Vegetated Wetlands in Virginia by Watershed (area in acres)						
	Vegetated Wetland Type				Wetland	Isolated	% of Total
	Palustrine	Lacustrine	Riverine	Estuarine	Total Area	Wetland Area	Wetland Area
Appomattox River	52,429	13	6	0	52,448	1,763	3
Ararat River	29	0	0	0	29	9	29
Atlantic Ocean	20,890	0	0	85,723	106,613	2,226	2
Big Sandy River	96	0	0	0	96	10	11
Chesapeake Bay	101,404	1	0	50,126	151,531	17,153	11
Chowan River	386,560	10	0	11,812	398,382	26,996	7
Clinch River	1,018	0	0	0	1,018	335	33
Holston River	639	0	0	0	639	130	20
Lower James River	111,651	21	187	17,458	129,317	18,630	15
Lower Potomac River	59,840	31	277	4,152	64,300	4,603	7
Middle James River	33,301	0	0	0	33,301	2,166	7
New River	1,870	0	0	0	1,870	571	31
Rappahannock River	56,798	12	97	10,262	67,169	5,376	8
Roanoke River	59,934	86	0	0	60,020	3,002	5
Upper James River	2,782	0	0	0	2,782	766	28
Upper Potomac River	5,025	3	0	0	5,028	1,779	35
York River	100,368	44	0	15,704	116,116	7,567	7
TOTAL	994,634	221	567	195,237	1,190,659	93,082	8

Table 2. Headwater wetlands by watershed, wetlands type, and stream order (area in acres)

Watershed	Palustrine		Lacustrine		Riverine		Total Area
	1st order	2nd order	1st order	2nd order	1st order	2nd order	
Lower Potomac River	20,029	9,716	1	20	31	93	29,890
Upper Potomac River	798	363	3	0	0	0	1,164
Chesapeake Bay	56,087	8,253	0	0	0	0	64,340
Atlantic Ocean	12,417	1,065	0	0	0	0	13,482
Rappahannock River	19,515	9,799	0	12	54	0	29,380
York River	26,494	16,646	42	0	0	0	43,182
Lower James River	42,617	13,274	20	0	26	15	55,952
Middle James River	5,849	7,829	0	0	0	0	13,678
Upper James River	507	238	0	0	0	0	745
Appomattox River	10,840	10,334	13	0	0	6	21,193
Chowan River	181,221	39,062	7	3	0	0	220,293
Roanoke River	10,056	10,928	0	0	0	0	20,984
Ararat Rover	6	0	0	0	0	0	6
New River	531	197	0	0	0	0	728
Holston River	247	104	0	0	0	0	351
Clinch River	210	233	0	0	0	0	443
Big Sandy River	26	45	0	0	0	0	71
TOTAL	387,450	128,086	86	35	111	114	515,882