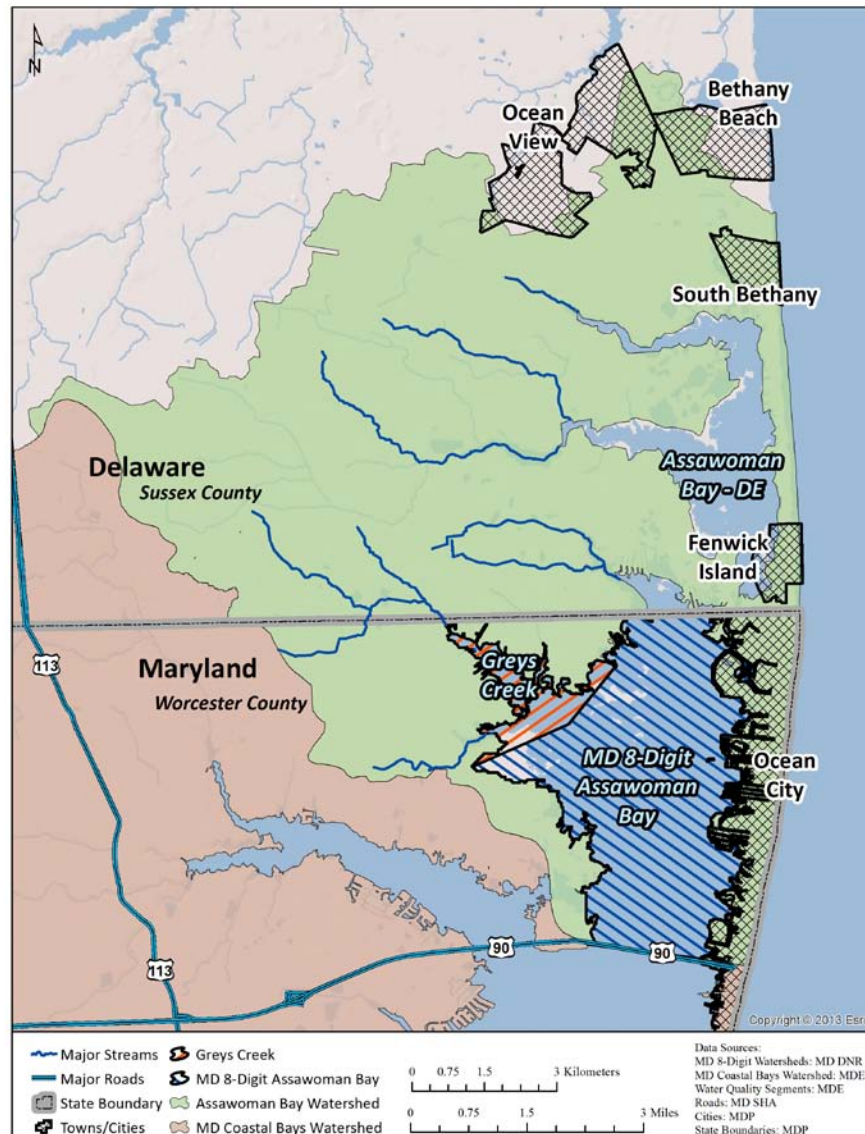


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## Appendix A: Assawoman Bay

## 1.0 Introduction

As described in the main TMDL report, the Coastal Bays are a shallow coastal lagoon system comprised of several individual and distinct waterbodies. Assawoman Bay is the northern-most of these waterbodies. The bay is located on the Atlantic Coast of the Delmarva (Delaware-Maryland-Virginia) Peninsula, and its watershed includes portions of Worcester County, Maryland and Sussex County, DE. Areas of interest in the Assawoman Bay watershed are Ocean City (MD), Fenwick Island (DE), South Bethany (DE), Bethany Beach (DE), and Ocean View (DE). Assawoman Bay connects to the Atlantic Ocean through the Isle of Wight Bay and ultimately through the Ocean City Inlet. Figure A1 shows the location of Assawoman Bay and its watershed.



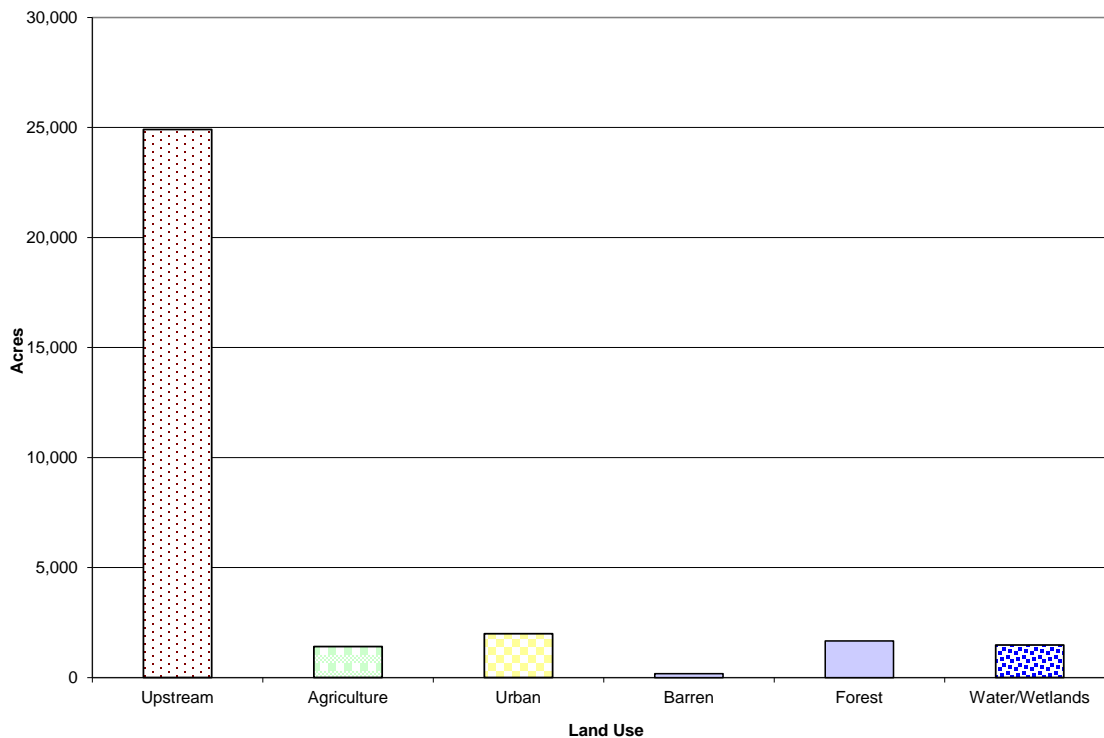
**Figure A1: Location map of the Assawoman Bay Watershed**

The major tributary draining to Assawoman Bay is Greys Creek. TMDLs have been developed for the Maryland portion of the Assawoman Bay, referred to as the MD 8-Digit Assawoman Bay (basin code: 02130102), and Greys Creek. Specific WLAs and LAs are provided for the portions of the watersheds within Maryland; however, aggregate Upstream LAs are also specified for the portions of the watersheds within Delaware. In the sections below, more detailed information regarding watershed characteristics, water quality, baseline nutrient loadings, and the specific TMDLs developed for the MD 8-Digit Assawoman Bay and Greys Creek are provided.

## 2.0 Land Use

### Assawoman Bay

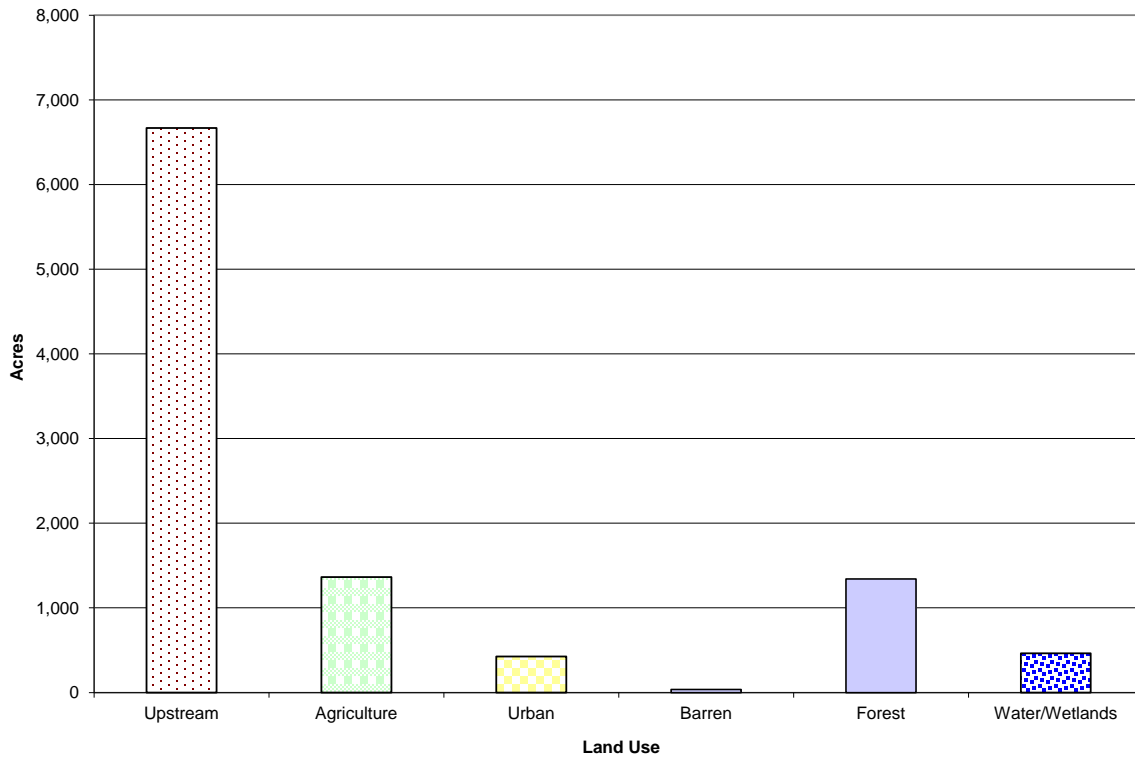
The Assawoman Bay watershed has a drainage area of 31,618 acres. The average depth of the bay is 3.3 ft (1 m), with a maximum depth of 8 ft (2.5 m) in the middle of the bay. The land use distribution in the watershed consists of mixed agriculture (1,403 acres, or 4% of the total watershed area); upstream drainage (24,909 acres, 79%); water/wetland (1,477 acres, 5%); urban (1,993 acres, 6%); forest and other herbaceous (1,660 acres, 5%); and barren (175 acres, 1%). Figure A2 shows the relative amounts of the different land uses in the Assawoman Bay watershed.



**Figure A2: Proportions of land use draining the Assawoman Bay watershed.**

**Greys Creek**

Greys Creek, a sizable waterbody located entirely within the Maryland portion of the Assawoman Bay, drains a watershed area of approximately 10,302 acres. Portions of the watershed area draining to Greys Creek, however, are located within Delaware. The Greys Creek watershed land use distribution consists of mixed agriculture (1,365 acres, or 13% of the total watershed area); upstream drainage (6,667 acres, 65%); forest and other herbaceous cover (1,341 acres, 13%); water/wetlands (465 acres, 5%); urban (426 acres, 4%); and barren (38 acres, <1%). Figure A3 shows the relative amounts of the different land uses in the Greys Creek watershed.



**Figure A3: Proportions of land use draining the Greys Creek watershed.**

### 3.0 Watershed Model Information

The applicable Assawoman Bay and Greys Creek watershed model segments and water quality monitoring stations are presented in the Tables A1 and A2 below.

**Table A1: Assawoman Bay and Greys Creek watershed model segments**

<b>Watershed Name</b>	<b>Watershed Model Segments</b>
Assawoman Bay	6, 7, 8, 9, 18, 19, 20, 150, 236, 330, 350, 370, 380, 410, 440 and the segments listed for Greys Creek
Greys Creek	10, 11, 12, 13, 14, 15, 16, 146, 147, 148, 149, 360

**Table A2: Assawoman Bay water quality monitoring stations**

<b>Waterbody</b>	<b>Stations</b>
Assawoman Bay <sup>1</sup>	XDN6454
	XDN4851
	XDN3445
Greys Creek	XDN5737

<sup>1</sup>All stations located in MD 8-digit portion of Assawoman Bay

### 4.0 Point Sources: National Pollutant Discharge Elimination System (NPDES) Loads

Table A3 below provides information on process water point source facilities with permits regulating the discharge of nutrients within the Assawoman Bay watershed. As described in the main TMDL report, there are no NPDES-regulated stormwater facilities in the entire Maryland Coastal Bays watershed.

**Table A3: Average daily flows and estimated annual TN and TP loads for process water point sources to the MD 8-Digit Assawoman Bay, 2001 – 2004.**

Watershed Model Segment	State	Facility	Type	Average Flow (MGD)	Estimated Delivered TN Load (lbs/yr)	Estimated Delivered TP Load (lbs/yr)
150	Maryland	Lighthouse Sound WWTP	Spray Irrigation	0.038	183	0

## 5.0 Nonpoint Source Loads

### Urban Stormwater, Agricultural, Atmospheric Deposition and Shoreline Erosion Loads

Nonpoint source loads and urban stormwater loads were estimated using the HSPF watershed model. As explained in the main report, since there are no NPDES stormwater permits within the watershed, urban stormwater loads are presented here as nonpoint sources. Atmospheric deposition loads were estimated using data from the National Atmospheric Deposition Program, which collects data at Assateague Island National Seashore. Shoreline erosion loads were estimated based on the work of Wells, Hennessee, and Hill (2002 and 2003), and Wells *et al.* (2008). Methods are described in the main report, with full details available in Wang *et al.* 2013 and VIMS 2013.

### On-Site Wastewater Disposal (Septic Systems) Loads

Septic system loading estimates were calculated using 2000 U.S. Census data, the USEPA-CBP sewer service area GIS coverage, the USEPA-CBP land river segment GIS coverage, the 1997 DNREC septic system GIS coverage, the MDE-WMA septic system GIS coverage, and the Maryland Coastal Bays TMDL HSPF watershed model GIS segmentation created by MDE. The assumptions used in the analysis are presented in Table A4. These loads were calculated based on a methodology used by the USEPA-CBP. Table A5 presents the calculated septic system loads for the Assawoman Bay 8-Digit watershed segments.

**Table A4: Assumptions used in the septic load analysis**

Assumption	Within 1,000ft of surface water	Greater than 1,000ft from surface water
Average # persons/septic	3.2	
Nitrogen loading per Person (lbs/year)	9.5	
Nitrogen loading per septic (lbs/year)	30.4	
Nitrogen attenuation rate	0.2	0.7
Surface water delivered nitrogen load per septic with attenuation (lbs/year)	24.32	9.12

**Table A5: Delivered septic loads and values used in the Coastal Bays Model for Assawoman Bay and Greys Creek.**

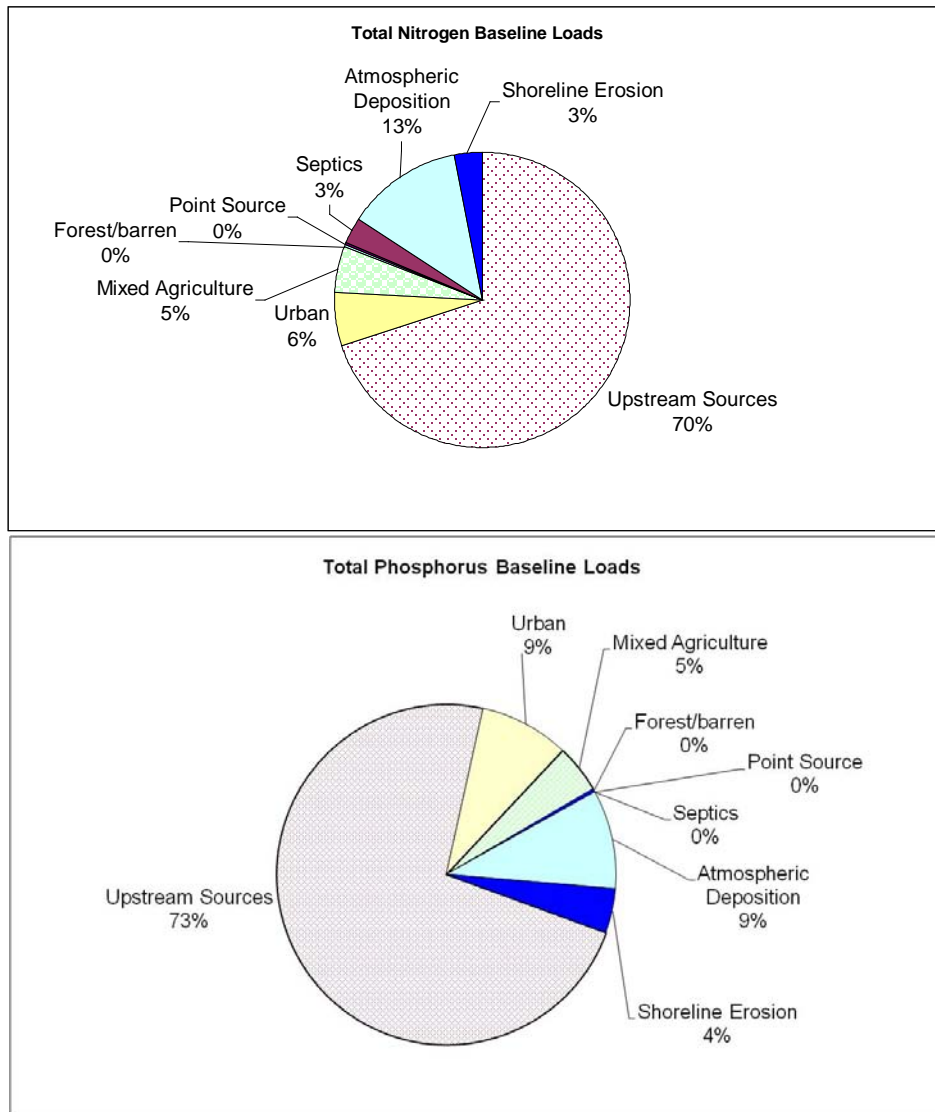
<i>SEGMENT</i>	<i>MD # Septics (within 1,000 ft)</i>	<i>MD # Septics (outside 1,000 ft)</i>	<i>Upstream # Septics (within 1,000 ft)</i>	<i>Upstream # Septics (outside 1,000 ft)</i>	<i>Total # Septics (within 1,000 ft)</i>	<i>Total # Septics (outside 1,000 ft)</i>	<i>Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/year)</i>	<i>Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/year)</i>	<i>Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/day)</i>	<i>Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/day)</i>	<i>Total Surface Water Delivered Nitrogen Load with Loss (lbs/day)</i>
6	0	0	1	0	1	0	24	0	0.07	0.00	0.07
7	0	0	8	55	8	55	195	502	0.53	1.37	1.91
8	0	0	1	14	1	14	24	128	0.07	0.35	0.42
9	0	0	0	1	0	1	0	9	0.00	0.02	0.02
10	3	0	13	11	16	11	389	100	1.07	0.27	1.34
11	49	0	3	0	52	0	1265	0	3.46	0.00	3.46
12	24	0	6	0	30	0	730	0	2.00	0.00	2.00
13	11	17	0	114	11	131	268	1195	0.73	3.27	4.01
14	5	0	0	0	5	0	122	0	0.33	0.00	0.33
15	0	1	0	0	0	1	0	9	0.00	0.02	0.02
16	19	46	0	0	19	46	462	420	1.27	1.15	2.42
18	1	4	0	0	1	4	24	36	0.07	0.10	0.17
19	0	3	0	0	0	3	0	27	0.00	0.07	0.07
147	11	0	0	0	11	0	268	0	0.73	0.00	0.73
148	33	0	0	0	33	0	807	2	2.21	0.00	2.21
149	58	0	0	0	58	0	1411	0	3.86	0.00	3.86
330	0	0	0	91	0	91	0	830	0.00	2.27	2.27
350	0	0	79	356	79	356	1921	3247	5.26	8.90	14.16
360	0	0	17	289	17	289	413	2636	1.13	7.22	8.35
370	0	0	65	458	65	458	1581	4177	4.33	11.44	15.77
410	0	0	143	344	143	344	3478	3137	9.53	8.60	18.12
440	0	0	2	0	2	0	49	0	0.13	0.00	0.13
Totals	214	71	338	1,733	552	1,804	13,429	16,454	36.79	45.08	81.87

## 6.0 Baseline Load Summary

### Assawoman Bay

The baseline average annual total nitrogen load to the MD 8-Digit Assawoman Bay is 360,653 lbs/yr. Upstream loads account for 70% of the total baseline nitrogen load. In Maryland's portion for the watershed, direct atmospheric deposition to the water's surface accounts for 13% and shoreline erosion comprises 3% of the baseline nitrogen load. Mixed agriculture (5%), urban (6%) and septic (3%) within Maryland's portion of the watershed account for the remaining nitrogen baseline load. The estimated average annual total phosphorus load is 23,923 lbs/yr. Upstream loads account for 73% of the total baseline phosphorus load. In Maryland's portion of the watershed, direct atmospheric deposition to the water's surface accounts for approximately 9% and shoreline erosion comprises 4% of the baseline phosphorus load. Mixed agriculture (5%) and urban (9%), within Maryland's portion of the watershed, account for the remaining phosphorus baseline load. There is one NPDES-regulated point source facility with a permit regulating the discharge of nutrients in the Maryland portion of the watershed; however, the nonpoint source load comprises the majority of the total load to the waterbody. Figure A4 shows the relative contributions of nitrogen and phosphorus from the various sources. Details can be found in Wang *et al.* (2013) and VIMS (2013).

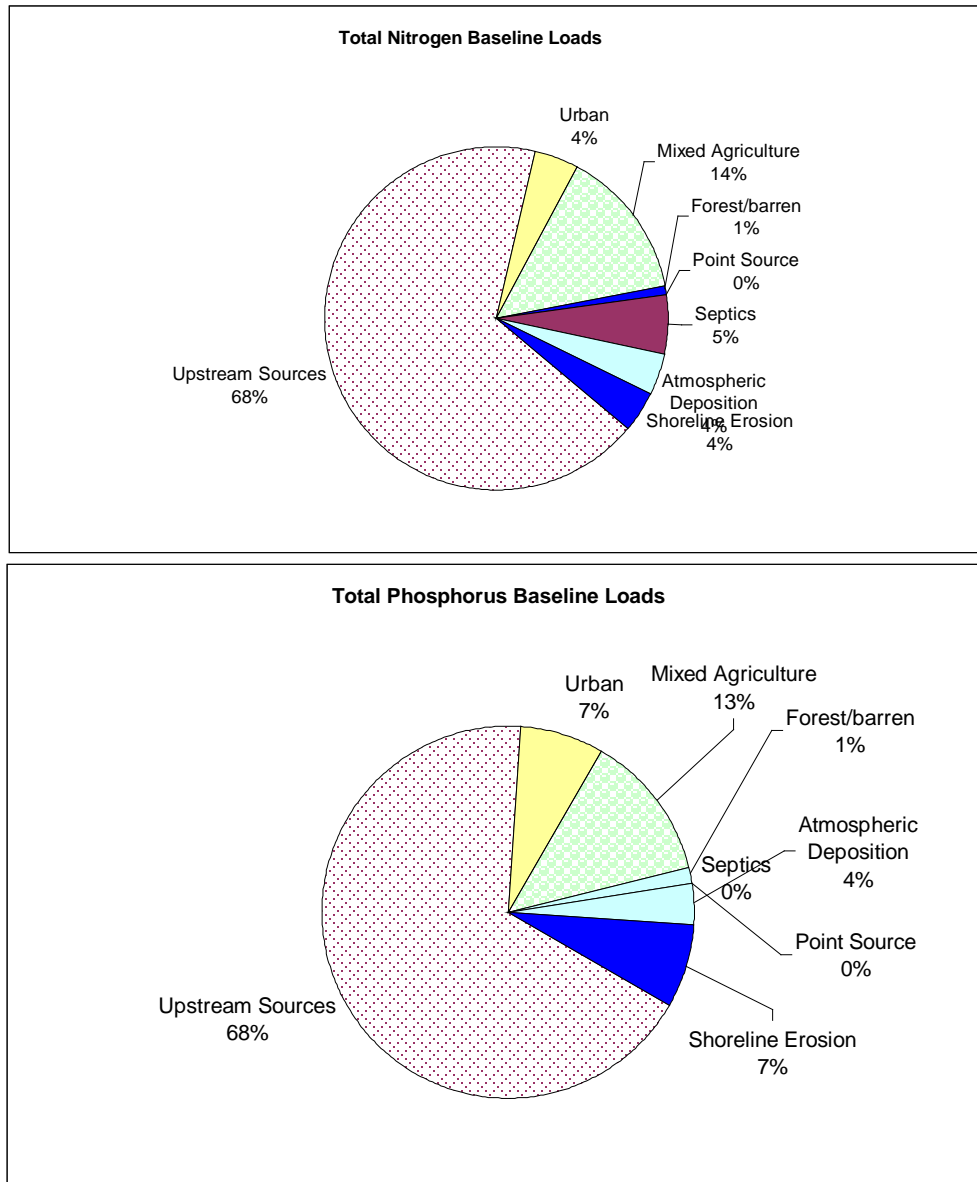




**Figure A4: Nitrogen and phosphorus contributions from various sources to the MD 8-Digit Assawoman Bay**

### **Grey's Creek**

The baseline average annual total nitrogen load to Greys Creek is 124,228 lbs/yr. Upstream loads account for 68% of the total baseline nitrogen load. In Maryland's portion of the watershed, direct atmospheric deposition to the water's surface accounts for approximately 4% and shoreline erosion comprises 4% of the baseline nitrogen load. Mixed agriculture (14%), urban (4%), septics (5%) and forest/barren (1%) within Maryland's portion of the watershed account for the remaining nitrogen baseline load. The estimated average annual total phosphorus load is 8,379 lbs/yr. Upstream loads account for 68% of the total baseline phosphorus load. In Maryland's portion of the watershed, direct atmospheric deposition to the water's surface accounts for approximately 4% and shoreline erosion comprises 7% of the baseline phosphorus load. Mixed agriculture (13%), urban (7%) and forest/barren (1%), within Maryland's portion of the watershed, account for the remaining phosphorus baseline load. There are no point sources with permits regulating the discharge of nutrients within the Greys Creek watershed; therefore, the nonpoint source load comprises the entire load to the waterbody. Figure A5 shows the relative contributions of nitrogen and phosphorus from the various sources. Details can be found in Wang *et al.* (2013) and VIMS (2013).



**Figure A5: Nitrogen and phosphorus contributions from various sources to Greys Creek**

### 7.0 Summary of TMDLs for the MD 8-Digit Assawoman Bay

Load reductions are applied only to controllable sources. Controllable sources are urban land, mixed agricultural land, and septic sources (nitrogen). For the purposes of this TMDL, shoreline erosion is not considered a controllable source. The reductions applied to atmospheric deposition were based on the allocation scenario (2025) for Worcester County in the Chesapeake Bay TMDL. See USEPA (2010) for further details regarding atmospheric deposition reductions. A load reduction of 20% was applied to controllable sources within the watershed.

TMDL Equation:

$$\text{TMDL} = \text{Upstream Loads} + \text{WLA}_{\text{Process Water}} + \text{WLA}_{\text{CAFO}} + \text{LA} + \text{MOS}$$

**Table A6: MD 8-Digit Assawoman Bay Average Annual Nitrogen TMDL (lbs/yr)**

Basin Name	TMDL	Upstream Loads <sup>1</sup> (WLA+LA)	WLA <sub>Process Water</sub>	WLA <sub>CAFO</sub>	LA	MOS
Assawoman Bay <sup>2</sup>	300,669	204,889	183	678	94,919	Implicit

<sup>1</sup> Upstream Loads denotes loadings from outside Maryland’s portion of the watershed. This allocation includes point and nonpoint sources.

<sup>2</sup> This allocation includes the allocations for Greys Creek.

**Table A7: MD 8-Digit Assawoman Bay Growing Season Nitrogen TMDL (lbs/growing season)**

Basin Name	TMDL	Upstream Loads <sup>1</sup> (WLA+LA)	WLA <sub>Process Water</sub>	WLA <sub>CAFO</sub>	LA	MOS
Assawoman Bay <sup>2</sup>	143,441	96,044	0	339	47,058	Implicit

<sup>1</sup> Upstream Loads denotes loadings from outside Maryland’s portion of the watershed. This allocation includes point and nonpoint sources.

<sup>2</sup> This allocation includes the allocations for Greys Creek.

**Table A8: MD 8-Digit Assawoman Bay Nitrogen Maximum Daily Load (lbs/day)**

Basin Name	MDL	Upstream Loads <sup>1</sup> (WLA+LA)	WLA <sub>Process Water</sub>	WLA <sub>CAFO</sub>	LA	MOS
Assawoman Bay <sup>2</sup>	2,080	1,542	1	2	536	Implicit

<sup>1</sup> Upstream Loads denotes loadings from outside Maryland’s portion of the watershed. This allocation includes point and nonpoint sources.

<sup>2</sup> This allocation includes the allocations for Greys Creek.

**Table A9: MD 8-Digit Assawoman Bay Average Annual Phosphorus TMDL (lbs/yr)**

Basin Name	TMDL	Upstream Loads <sup>1</sup> (WLA+LA)	WLA <sub>Process Water</sub>	WLA <sub>CAFO</sub>	LA	MOS
Assawoman Bay <sup>2</sup>	19,985	13,501	0	56	6,428	Implicit

<sup>1</sup> Upstream Loads denotes loadings from outside Maryland’s portion of the watershed. This allocation includes point and nonpoint sources.

<sup>2</sup> This allocation includes the allocations for Greys Creek.

**Table A10: MD 8-Digit Assawoman Bay Growing Season Phosphorus TMDL (lbs/growing season)**

Basin Name	TMDL	Upstream Loads <sup>1</sup> (WLA+LA)	WLA <sub>Process Water</sub>	WLA <sub>CAFO</sub>	LA	MOS
Assawoman Bay <sup>2</sup>	10,196	6,887	0	28	3,281	Implicit

<sup>1</sup> Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.

<sup>2</sup> This allocation includes the allocations for Greys Creek.

**Table A11: MD 8-Digit Assawoman Bay Phosphorus Maximum Daily Load (lbs/day)**

Basin Name	MDL	Upstream Loads <sup>1</sup> (WLA+LA)	WLA <sub>Process Water</sub>	WLA <sub>CAFO</sub>	LA	MOS
Assawoman Bay <sup>2</sup>	147	106	0	0.2	41	Implicit

<sup>1</sup> Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.

<sup>2</sup> This allocation includes the allocations for Greys Creek.

**Table A12: MD 8-Digit Assawoman Bay Baseline Nitrogen Load, TMDL, and Total Reduction Percentage**

Baseline Load (lbs/yr)	TMDL (lbs/yr)	Total Reduction (%)
360,653	300,669	17

**Table A13: MD 8-Digit Assawoman Bay Baseline Phosphorus Load, TMDL, and Total Reduction Percentage**

Baseline Load (lbs/yr)	TMDL (lbs/yr)	Total Reduction (%)
23,924	19,985	16

**Table A14: Greys Creek Average Annual Nitrogen TMDL (lbs/yr)**

Basin Name	TMDL	Upstream Loads <sup>1</sup> (WLA+LA)	WLA <sub>Process Water</sub>	WLA <sub>CAFO</sub>	LA	MOS
Greys Creek	101,333	64,962	0	678	35,693	Implicit

<sup>1</sup> Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.

**Table A15: Greys Creek Growing Season Nitrogen TMDL (lbs/growing season)**

Basin Name	TMDL	Upstream Loads <sup>1</sup> (WLA+LA)	WLA <sub>Process Water</sub>	WLA <sub>CAFO</sub>	LA	MOS
Greys Creek	46,422	29,042	0	339	17,041	Implicit

<sup>1</sup> Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.

**Table A16: Greys Creek Nitrogen Maximum Daily Load (lbs/day)**

Basin Name	MDL	Upstream Loads <sup>1</sup> (WLA+LA)	WLA <sub>Process Water</sub>	WLA <sub>CAFO</sub>	LA	MOS
Greys Creek	782	517	0	2	264	Implicit

<sup>1</sup> Upstream Loads denotes loadings from outside Maryland’s portion of the watershed. This allocation includes point and nonpoint sources.

**Table A17: Greys Creek Average Annual Phosphorus TMDL (lbs/yr)**

Basin Name	TMDL	Upstream Loads <sup>1</sup> (WLA+LA)	WLA <sub>Process Water</sub>	WLA <sub>CAFO</sub>	LA	MOS
Greys Creek	6,847	4,375	0	56	2,416	Implicit

<sup>1</sup> Upstream Loads denotes loadings from outside Maryland’s portion of the watershed. This allocation includes point and nonpoint sources.

**Table A18: Greys Creek Growing Season Phosphorus TMDL (lbs/growing season)**

Basin Name	TMDL	Upstream Loads <sup>1</sup> (WLA+LA)	WLA <sub>Process Water</sub>	WLA <sub>CAFO</sub>	LA	MOS
Greys Creek	3,446	2,194	0	28	1,223	Implicit

<sup>1</sup> Upstream Loads denotes loadings from outside Maryland’s portion of the watershed. This allocation includes point and nonpoint sources.

**Table A19: Greys Creek Phosphorus Maximum Daily Load (lbs/day)**

Basin Name	MDL	Upstream Loads <sup>1</sup> (WLA+LA)	WLA <sub>Process Water</sub>	WLA <sub>CAFO</sub>	LA	MOS
Greys Creek	53	34	0.00	0.2	19	Implicit

<sup>1</sup> Upstream Loads denotes loadings from outside Maryland’s portion of the watershed. This allocation includes point and nonpoint sources.

**Table A20: Greys Creek Nitrogen Baseline Load, TMDL, and Total Reduction Percentage**

Baseline Load (lbs/yr)	TMDL (lbs/yr)	Total Reduction (%)
124,228	101,333	18

**Table A21: Greys Creek Phosphorus Baseline Load, TMDL, and Total Reduction Percentage**

Baseline Load (lbs/yr)	TMDL (lbs/yr)	Total Reduction (%)
8,379	6,847	18