Maryland Coastal Bays Watershed Modeling Report

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List of Abbreviations

AI	Assateague Island
CBP-P5	Chesapeake Bay Program Phase 5 Community Watershed Model
cfs	Cubic Feet per Second
DO	Dissolved Oxygen
DE	Delaware
DEM	Digital Elevation Model
DNR	Department of Natural Resources
DNREC	Delaware Department of Natural Resources and Environmental Control
ET	Evapotranspiration
EOS	Edge of Stream
GPD	Gallons per Day
HSPF	Hydrological Simulation Program - FORTRAN
lb	Pound
MCB	Maryland Coastal Bays
MCBW	Maryland Coastal Bays Watershed
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
mg/l	Milligrams per Liter
N	Nitrogen
NH4	Ammonia
NO3	Nitrate
OC	Ocean City
ORGN	Organic Nitrogen
ORGP	Organic Phosphorus
P	Phosphorus
PEST	Parameter Estimator
PO4	Phosphate
SAV	Submerged Aquatic Vegetation
SCS	Soil Conservation Service (USDA)
SH	Snow Hill
SV	Selbyville
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solid
UMCP	University of Maryland College Park
USDA	US Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	US Geological Survey
VA	Virginia
VADEQ	Virginia Department of Environmental Quality
VIMS	Virginia Institute of Marine Science
WA	Wallops Island
WASP	Water Quality Analysis Simulation Program
WT	Water Temperature
WWTP	Wastewater Treatment Plant

Executive Summary

The Maryland Coastal Bays (MCBs) are a collection of water bodies including Assawoman Bay, Isle of Wight Bay, Sinepuxent Bay, Newport Bay, and Chincoteague Bay located in the Mid-Atlantic Bight (see Figure 1). The MCBs constitute a shallow lagoon system connecting to Atlantic Ocean through two inlets: Ocean City Inlet to the north and Chincoteague Inlet to the south. The MCBs drain from a small coastal watershed with an area of approximately 175 square miles. Tidal range near the Ocean City Inlet is more than 3.4 feet, while it drops to 0.4 feet in the middle of Chincoteague Bay and 1.5 feet in Assawoman Bay. The depth is generally less than 10 feet.

The MCBs are currently having degraded water quality conditions, such as excessive nutrients, low dissolved oxygen, occasional high levels of chlorophyll a concentration associated with algal bloom in some areas and are projected to experience environmental stress due to increased population and intense development (Wazniak et al., 2007; MDE, 2002). Under Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations, Maryland identified the Maryland Coastal Bays as impaired by nutrients in 1996/1998. Therefore, a development of a Total Maximum Daily Load (TMDL) for each listed segment is required.

The Hydrological Simulation Program - FORTRAN (HSPF) framework was used to simulate watershed hydrological and nutrients transport processes of the MCBs watershed. This report describes the development and the calibration of the hydrological and water-quality models of the watershed of the MCBs performed through a cooperative effort between the Maryland Department of the Environment (MDE) and Virginia Institute of Marine Science (VIMS). The study area consists of the Maryland, Virginia, and Delaware portions of the Coastal Bays watershed. The model predictions will provide the information needed to fulfill regulatory requirements of the TMDL process including (1) the seasonal environmental variations of nutrient loads, (2) predictions under critical environmental conditions, and (3) serve as the avenue to evaluate scenarios with reasonable assurance that the TMDLs can be met. The model will also provide the edge-of-stream loads input for the hydrodynamic and water quality model of the MD Coastal Bays also developed by the Virginia Institute of Marine Science (VIMS).

The edge-of-stream loads for Virginia and Delaware, and the Maryland portion of the watershed are listed in Table 1. A detail distribution of each waterbody is listed in Table 2.

Table 1. Predicted nutrient (lbs) and sediment loads (tons) for the Coastal Bays watershed and the Maryland portion of the watershed.

		1999	2000	2001	2002	2003	2004	2005*
MD-VA-DE	TN	928,180	1,197,762	844,738	520,571	1,549,662	1,680,086	1,406,609
	TP	71,904	80,129	51,511	29,618	121,621	147,999	117,545
	SED	107,845	102,808	53,539	47,271	130,592	176,075	152,310
Maryland	TN	660,410	452,847	291,619	860,181	941,729	780,969	660,410
	TP	43,105	27,333	16,259	68,541	83,805	66,405	43,105
	SED	78,433	72,922	36,974	35,539	93,755	124,120	107,738

***** The load estimated for 2005 is only from January through August

		1999	2000	2001	2002	2003	2004	2005*
Assawoman	TN	222,857	265,675	165,000	123,513	356,218	382,076	309,802
Wight		257,267	305,314	192,341	149,140	408,905	436,454	351,603
Newport		120,198	147,554	93,128	60,761	199,635	221,706	184,565
Sinepuxent		26,682	28,574	19,879	19,291	37,903	41,285	34,562
Chincoteague		301,176	450,645	374,389	167,866	547,000	598,565	526,077
Assawoman	TP	17,892	18,255	10,244	7,567	2,9179	36,386	28,310
Wight		20,185	20,177	11,457	8,961	33,439	40,446	31,567
Newport		9,288	9,460	5,361	3,365	16,155	19,972	15,898
Sinepuxent		2,279	2,049	1,153	1,103	3,714	4,933	3,928
Chincoteague		22,260	30,187	23,296	8,622	39,133	46,262	37,842
Assawoman	TS	28,844	26,108	12,664	12,897	34,979	45,341	37,976
Wight		37,859	33,691	16,145	17,923	44,593	56,558	48,082
Newport		14,970	13,306	6,452	6,412	18,024	24,476	21,385
Sinepuxent		5,998	5,126	2,414	2,947	6,811	8,582	7,503
Chincoteague		20,174	24,576	15,863	7,091	26,185	41,119	37,364

Table 2. Predicted nutrient (lbs) and sediment loads (tons) for the Coastal Bays (each Bay watershed in the Coastal Bays).

***** The load estimated for 2005 is only from January through August

1.0 Introduction

The Maryland Coastal Bays (MCBs) are a collection of water bodies including Assawoman Bay, Isle of Wight Bay, Sinepuxent Bay, Newport Bay, and Chincoteague Bay located in the Mid-Atlantic Bight (see Figure 1). The MCBs constitute a shallow lagoon system connecting to Atlantic Ocean through two inlets: Ocean City Inlet to the north and Chincoteague Inlet to the south. Its depth is generally less than 10 feet, draining from a small coastal watershed with an area of approximately 175 square miles. River input and surface runoff is low and groundwater is an important source of freshwater inflow. Hydrodynamics in the MCBs are mainly controlled by tides and winds. Tidal range near the Ocean City Inlet is more than 3.4 feet, while it drops to 0.4 feet in the middle of Chincoteague Bay and 1.5 feet in Assawoman Bay. Strong mixing usually occurs when wind is blowing across these shallow waters. Due to limited connection to the ocean as well as only moderate freshwater input, flushing in the bays is very slow. It usually takes months to replace all of the water within the bays by freshwater and ocean exchange (Wang, 2009).

The MCBs are currently having degraded water quality conditions, such as excessive nutrients, low dissolved oxygen, occasionally high levels of chlorophyll a concentration associated with algal blooms in some areas and are projected to experience environmental stress due to increased population and intense development (Wazniak et al., 2004; MDE, 2005). Under Section 303(d) of the Clean Water Act and EPA's Water-Quality Planning and Management Regulations, Maryland identified the Maryland Coastal Bays as impaired by nutrients in 1996/1998. Therefore, a development of a Total Maximum Daily Load (TMDL) for each listed segment is required.

In order to assist in management decisions to protect the environmental quality of the MCBs and develop TMDLs, a three-dimensional hydrodynamic and water quality numerical model has been developed for synthesizing the multi-stressors in the system, simulating the direct and indirect responses linking between sediment and water column nutrient dynamics, and conducting scenarios studies to address the ecosystem restoration alternatives. A watershed model has been developed to simulate flow, and nutrients and sediment loadings using Hydrologic Simulation Program Fortran (HSPF). The model simulations provide nonpoint source loadings for the 3-D hydrodynamic and water quality model of the MCBs for model calibration and TMDL study. The model simulation period spans from 1999-2005. This report documents the procedures of the watershed model development.

2.0 Purpose and Scope

The purpose of this study is to develop a watershed model of the MCBs and provide flow, nutrients, and sediment loadings to a three-dimensional eutrophication model to develop TMDLs for the MCBs. The Scope of the work includes:

1. Update existing watershed model setup, model parameters, and nutrient sources including nutrient applications, septic, point source, and atmospheric deposition.

2. Calibrate the watershed model for modeling hydrology and nutrient transport processes for selected locations to ensure the model simulations are accurate.

3. Conduct scenario simulation studies as required management scenarios and link model results to the 3D model of the MCBs.

4. Compile model results for TMDL report.

3.0 Watershed Characteristics

3.1 Basin Description

The MD 8-digit watersheds draining into the Maryland Coastal Bays are Assawoman Bay, Isle of Wight Bay (including St. Martin's River and Marshall Creek), Sinepuxent Bay, Newport Bay, and Chincoteague Bay. This shallow coastal lagoon system spans three states, the majority of which lies in Maryland. The Maryland Coastal Bays are located on the Atlantic Coast of the Delmarva (Delaware-Maryland-Virginia) Peninsula and their watersheds include portions of Worcester County, Maryland, Sussex County, Delaware, and Accomack County, Virginia (Figure 1). Major areas of interest in the watersheds are Ocean City, Assateague Island National Seashore, Ocean Pines, Berlin, Chincoteague National Wildlife Refuge, Wallops Island National Wildlife Refuge (VA), Shelbyville (DE), Fenwick Island (DE), South Bethany (DE), Bethany Beach (DE), and Ocean View (DE). The Coastal Bays connect to the Atlantic Ocean through two inlets: Ocean City Inlet and Chincoteague Inlet.

Natural water depths in the Coastal Bays are generally less than 10 feet except for the main navigation channels around the Inlets. The tidal range in the Coastal Bays varies by location. Tidal range near the Ocean City Inlet is more than 3.4 feet, while it drops to 0.4 feet in the middle of the Chincoteague and 1.5 feet in Assawoman Bay. Strong mixing usually occurs when wind blows across these shallow waters (Wang, 2009). The total land area of these watersheds draining to the Coastal Bays is 210,360 acres (851 square kilometers).

Table 3 shows the number of acres contained within each of the three States draining into the Coastal Bays System. Table 4 shows the area in acres for each of the watersheds draining into the Coastal Bays System.

Table 3. Coastal Bays Subwatershed Areas Within State Jurisdictions

Jurisdictions	Area (acres)
Delaware	31,442
Maryland	120,353
Virginia	58,565
Total	210,360

Table 4. Coastal Bays Subwatershed Areas

Subwatersheds	Area (acres)
Assawoman Bay	31,693
Isle of Wight	41,016
Sinepuxent Bay	7,647
Newport Bay	28,386
Chincoteague Bay	101,618
Entire Coastal Bays System	210,360

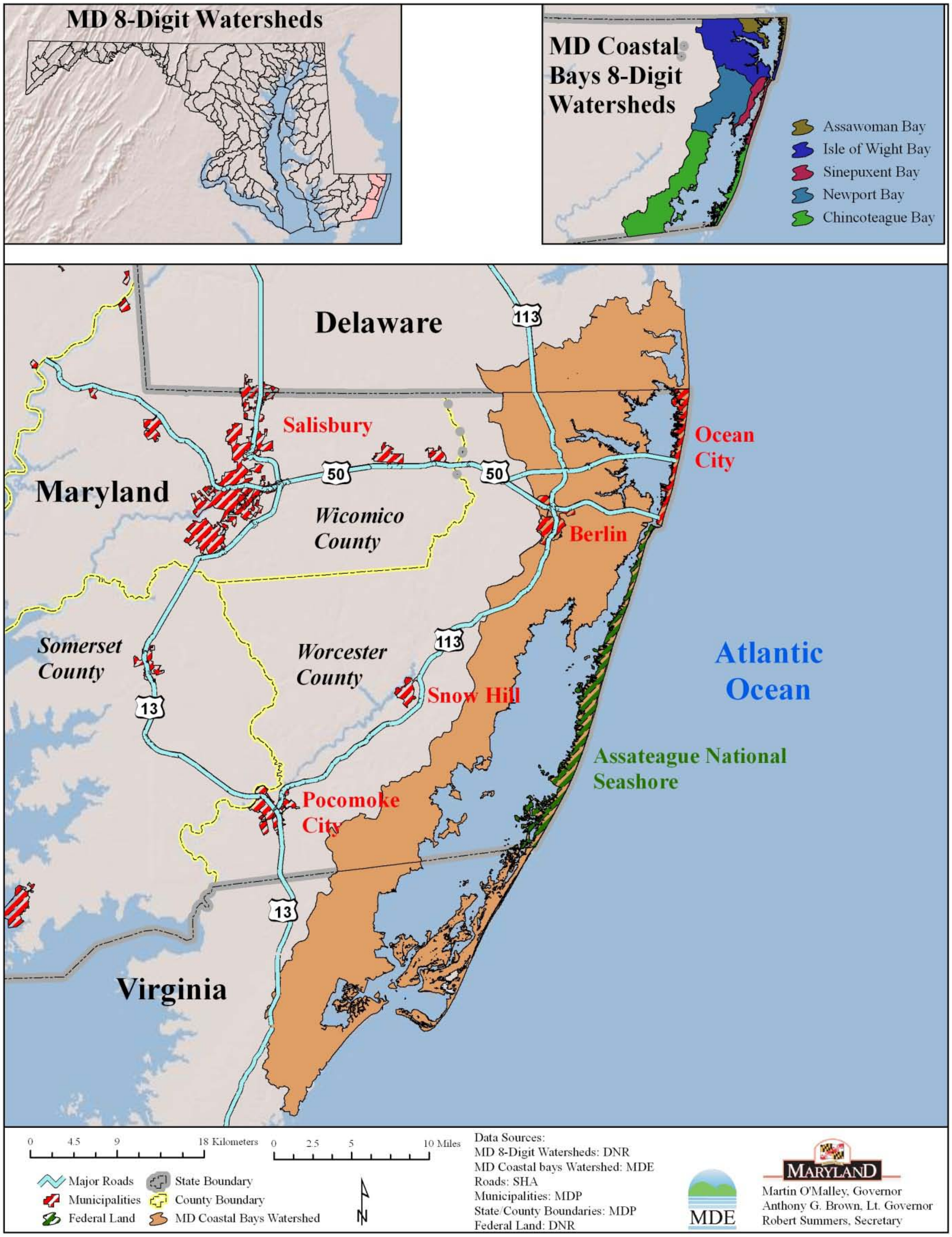

Figure 1. Location of the MD-VA-DE Coastal Bays watershed.

3.2 Geology

The watersheds draining into the Maryland Coastal Bays lie within the physiographic province of the Atlantic Coastal Plain and are about 110 miles east of the fall line that separates the Plain from the Piedmont Plateau. The Atlantic Coastal Plain surficial geology is characterized by thick, unconsolidated marine sediments deposited over the crystalline rock formations of the Piedmont Province. The soils are underlain by sediment consisting chiefly of gravel, silt, clay, sand and shell fragments. The depth of these soils is generally more than 1-mile thick but in the case of Ocean City the soil depth is more than 1.5-miles thick. Drainage is impeded in almost 75% of the acreage of soils in Worcester County. About 20% of the soils in Worcester County can be farmed without artificial drainage (USDA, SCS 1973).

The MD Coastal Bays watershed is an eroded plain with three main physiographic divisions: mainland, coastal beaches and the tidal marshes. All of the farmland is located on the mainland where the soils are generally level to undulating. Many areas of the mainland are a few feet above the normal level of the streams and in many places adjacent to marshland. The beaches are located mostly on the barrier islands of Fenwick, Assateague, and Chincoteague Islands. The tidal marshes are located on the eastern shores of the mainland and the western shores of the barrier islands. Submerged aquatic vegetation is also present in a number of these areas (USDA, SCS 1973).

4.0 HSPF Model Description and Structure

4.1 Previous TMDL Studies

MDE has established two sets of TMDLs for areas within the Maryland Coastal Bays: Northern Coastal Bays and Newport Bay. These previous studies were considered in this process. In 2003, Delaware Department of Natural Resources and Environmental Control (DNREC) and the U.S. Geological Survey (USGS) prepared an HSPF model for the Delaware Inland Bays including Assawoman Bay. These previous studies became the starting point for the current project. The previous MDE TMDLs had areas of the modeling domain where the calibration and/or specificity for certain areas of the watersheds were not conclusive for the establishment of TMDLs and therefore, TMDLs were not established for these areas. The current project will assist in the establishment of TMDLs for all areas of the Maryland Coastal Bays. In addition, the previous modeling efforts used a steady-state WASP model and the current effort uses a time-variable model. Further, the model calibration time period and the TMDL time periods are different between these efforts and therefore, a comparison cannot be made between previous efforts and the current project. For informational purposes, percent reductions have potential for comparison, however, given the reasons listed above, it is not recommended.

4.2 Overview of the Hydrological Simulation Program - FORTRAN (HSPF)

The HSPF model was used for this study. The HSPF model is a general watershed model and capable of simulating flow, and the fate and transport of pollutants over the entire hydrologic cycle. This model is used by the Chesapeake Bay Program for simulating watershed processes. Two distinct sets of processes are represented in HSPF: (1) processes that simulate flow and determine the fate and transport of pollutants at the surface and/or the subsurface of a watershed, and (2) in-stream processes. The former will be referred to as “land” or “watershed” processes, the latter as “in-stream” or “reach” processes.

Constituents can be represented at various levels of detail and simulated both for land and in-stream environments. These choices are made, in part, by specifying the modules that are used, and thus the choices establish the model structure used for any one situation. In addition to the choice of modules, other types of information must be supplied for the HSPF calculations, including model parameters and time series of input data. Time series of input data include meteorological data, point sources, reservoir information, and other type of continuous data as needed for model development.

A watershed is subdivided into model segments (subwatersheds), which are defined as areas with similar hydrologic characteristics and landuse. Within a model segment, multiple land use types can be simulated, each using different modules and different model parameters. In terms of simulation, all processes are computed for a spatial unit of 1 acre for each land use category. The flow, loadings of nutrients, and sediment fluxes of each acre is multiplied by the total acreage of the land use for each subwatershed to obtain total loadings for corresponding landuse of the subwatershed. Although the model simulation is performed on a temporal basis, land use information does not change with time. As a rule of thumb, the land use data that are used to describe the watershed conditions are usually chosen for the middle of the simulation period, so that the average land use conditions are represented.

Within HSPF, the RCHRES module sections are used to simulate stream reaches' hydrology, sediment transport, water temperature, and water quality processes that result in the delivery of flow and pollutant loading to a bay, reservoir, ocean, or any other body of water. Flow through a reach is assumed to be unidirectional. In the solution technique of normal advection, it is assumed that simulated constituents are mixed throughout the waters of the RCHRES; constituents move at the same horizontal velocity as the water and the inflow and outflow of materials are based on a mass balance. The HSPF model uses a convex routing method to move mass within the reach (Equation 4.2-1). Outflow may leave the reach through one of five possible exits (i.e., irrigation, municipal, and industrial water use, flowing to a downstream reach, etc.), and the processes occurring in the reach will be influenced by precipitation, evaporation, and other fluxes. The outflow is computed as:

$$ROVOL = (Ks * ROS + COKS * ROD) * DELTS \qquad (4.2\text{-}1)$$

Where ROVOL is the total outflow during the interval; Ks is a weighting factor ($0 \leq Ks \leq 0.99$); DELTS is the simulation interval in seconds; COKS is the complement of Ks (1 – Ks); ROS is the total rate of outflow at the start of the interval; and ROD is the total rate of demanded outflow at the end of the interval.

4.3 Model Assumptions

4.3.1 Contribution from the Delaware portion of the Coastal Bays

The HSPF model developed by the USGS for the Delaware Inland Bays watershed (Gutiérrez-Magness and Raffensperger, 2003) was extended to cover the period of the project (2000-2005) and used as the baseline model for the portion of the Coastal Bays watershed located in Delaware to predict the hydrology and nutrient loads in the area (MDE and UMCP, 2010). Because the previous model was not calibrated specifically for this region and there are no sufficient data to verify the loading from the Delaware portion of the watershed, the model outputs of unit loadings for each landuse category of the Delaware region were compared to the Chesapeake Bay Program watershed model results and published values in both Maryland and Virginia Coastal Bay areas for each nutrient species. An adjustment was implemented by using constant adjustment factors to ensure the loadings are within the acceptable range in this region. The accuracy of the adjustment factors was further verified through eutrophication processes simulations using three-dimensional model of the MCBs.

4.3.2 Wetlands Land Use

Although the HSPF has limitations in simulating chemical processes in wetlands, this category was currently simulated using the processes for the forest landuse, but uses a lower infiltration rate, providing a good estimation of total loading contribution. The land-use information was assumed not to change through time, which is the standard setting in the HSPF model (MDE and UMCP, 2010).

4.4 Watershed Segmentation

An initial model segmentation for the HSPF of MCBs was developed using the longest flow path and terrain characteristics as the criteria for segment delineation; the methodology for delineation using the longest flow path is described by Moglen and Casey (1998). For areas without a noticeable flow path along the shore, the Coastal Bays shore delineation (Hennessee et al., 2003) was used as the shoreline boundary of the HSPF model segments. Because of the regulatory purposes of the model application, the initial and more detailed delineation was modified by the MD 8-digit (Figure 2) boundary (except in the delineation of the Birch Branch model segment). An additional factor determining the final watershed segmentation was the need to associate the drainage points from the land segments with cells of the hydrodynamic model for the Maryland Coastal Bays. The segmentation from the HSPF model developed by the USGS for the Delaware Inland Bays watershed (Gutiérrez-Magness and Raffensperger, 2003) was used for the portion of the Coastal Bays watershed located in Delaware. The final delineation of the model has 202 model segments and it is shown in Figure 2. The model segments and their locations within the MD 8-digit, DE and VA watersheds are shown in Table 5.

Figure 2. HSPF Maryland Coastal Bays HSPF-model segmentation and SELFE hydrodynamic model grid

Table 5. Maryland 8-digit watersheds and HSPF Coastal Bays Model segments

MD 8-digits	HSPF model segment partially contained in MD 8-digits watershed	HSPF model segment fully contained in MD 8-digits watershed	HSPF model segment fully contained in DE watershed	HSPF model segment fully contained in VA watershed
02130102-Assawoman Bay	6, 9, 10, 11, 12, 13, 148	14, 15, 16, 18, 19, 20, 146, 147, 149, 150, 236	7, 8, 330, 350, 360, 370, 380, 410, 440	
02130103-Isle of Wight Bay	186	1, 2, 3, 4, 5, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 144, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 187, 510, 520		
02130104 – Sinepuxent Bay		58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 169, 170, 171, 172, 173, 174, 235		
02130105-Newport Bay		73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 143, 145, 175, 176, 177		
02130106-Chincoteague Bay	116, 117, 118, 120	85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 109, 110, 111, 112, 113, 114, 115, 179, 180, 181, 182, 183, 184, 237, 238, 239, 500		119, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 185, 240, 241

4.5 Land Use

Land use information was derived from the Delaware Office of Planning (I-Team) 2002 Land Use Database (2003), Maryland Worcester County 2004 Land Use database (2009), and for Virginia, 1999 National Land Cover Data (USGS, 1999). These datasets were combined after reclassification of the Worcester County dataset to the CBP-P5 land uses. The other data sets were in the CBP-P5 format.

4.5.1 Reclassification of the land use data provided by Worcester County (MDE and UMCP 2010)

The Worcester County land use information was highly detailed and, for the purposes of this study, was aggregated to CBP-P5 land use classifications. The reclassification of the database from Worcester County “Lndcvr04_DRAFT_1_29_09.gdb” provided in January 2009 by Worcester County was completed as described in Appendix A, “Report on the Reclassification of Land Use” dated February 2009. The purpose of the reclassification was to group categories that could be simulated in the model with similar hydrological characteristics and that the amounts and types of nutrients applied to the reclassified categories were also similar. Because of the HSPF limitations in simulating chemical processes in wetlands, this category was simulated as forest landuse, but assuming it associated with high watertable with low infiltration. A quality control for this reclassification was performed. The reclassification is shown in Table 6.

Table 6. Reclassification of Worcester Co. Land use categories into the HSPF-model simulated land uses

Worcester County classification	Worcester County Description	HSPF_ID classification	HSPF-ID Description
1	Airport	1	Impervious
1	Bare Ground	6	Bare
1	Basketball Court	1	Impervious
1	Bike Path	1	Impervious
1	Bike Path	1	Impervious
1	Boardwalk	1	Impervious
1	Building Footprint	1	Impervious
1	Commercial yard	8	Pervious Urban
1	Dirt Road	2	Pervious
1	Driveway	1	Impervious
1	Parking Lot	1	Impervious
1	Railroad	1	Impervious
1	Residential yard	1	Impervious
1	Residential yard	2	Pervious
1	Rip Rap	2	Pervious
1	Road Surface	2	Pervious
1	Road median	1	Impervious
1	Sidewalk	1	Impervious
1	Swimming Pool	1	Impervious
1	Swimming Pool	8	Pervious Urban
1	Tennis Court	1	Impervious
1	Trail	2	Pervious
1	Unpaved Driveway	2	Pervious
1	Unpaved Road	2	Pervious
2	Bay	4	Water
2	Pond	4	Water
2	River	4	Water
2	Stream	4	Water
3	Bare Buffer	6	Bare
3	Bare Ground	6	Bare
3	Borrow Pit	9	Pervious Urban
3	Brush	5	Forest
3	Cemetery	9	Pervious Urban
3	Commercial yard	8	Pervious Urban
3	Forest	5	Forest
3	Forest Median	5	Forest
3	Golf Course	9	Pervious Urban
3	Grass Median	9	Pervious Urban
3	Grassland	9	Pervious Urban
3	Park	9	Pervious Urban
3	Trail	9	Pervious Urban

Table 6. Reclassification of Worcester Co. Land use categories into the HSPF-model simulated land uses

Worcester County classification	Worcester County Description	HSPF_ID classification	HSPF-ID Description
3	Vegetated Buffer	5	Forest
3	Wetlands	4	water
4	Ag Operations	3	Agriculture
4	Field	3	Agriculture
4	Bare Buffer	6	Bare
4	Bare Ground	6	Bare
4	Beach	6	Bare
4	Brush	5	Forest
4	Commercial yard	8	Pervious Urban
4	Dirt Road	9	Pervious Urban
4	Driveway	9	Pervious Urban
4	Forest 5	5	Forest
4	Grassland	9	Pervious Urban
4	Park	9	Pervious Urban
4	Parking Lot	8	Pervious Urban
4	Residential yard	9	Pervious Urban
4	Trail	9	Pervious Urban
4	Unpaved Driveway	9	Pervious Urban
4	Vegetated Buffer	5	Forest
4	Wetlands	4	water
5	Ag Operations	3	Agriculture
5	Ag Operations	7	Pasture
5	Ag Operations	9	Pervious Urban
5	Ag Operations	10	Chicken Houses
5	Agriculture Field	3	Agriculture
5	Bare Buffer	6	Bare
5	Bare Ground	6	Bare
5	Brush	5	Forest
5	Commercial yard	8	Pervious Urban
5	Dirt Road	9	Pervious Urban
5	Driveway	9	Pervious Urban
5	Forest	5	Forest
5	Grassland	7	Pasture
5	Industrial	8	Pervious Urban
5	Pond	4	water
5	Residential yard	1	Impervious
5	Residential yard	9	Pervious Urban
5	Road Surface	8	Pervious Urban
5	Vegetated Buffer	5	Forest
5	Wetlands	4	water
6	Bare Buffer	6	Bare
6	Bare Ground	6	Bare
6	Brush	5	Forest
6	Commercial yard	8	Pervious Urban
6	Driveway	9	Pervious Urban
6	Forest	5	Forest
6	Forest Median	5	Forest
6	Grass Median	9	Pervious Urban

Table 6. Reclassification of Worcester Co. Land use categories into the HSPF-model simulated land uses

Worcester County classification	Worcester County Description	HSPF_ID classification	HSPF-ID Description
6	Grassland	5	Forest
6	Industrial	8	Pervious Urban
6	Residential yard	8	Pervious Urban
6	Vegetated Buffer	5	Forest
6	Wetlands	4	water

Table 7. Chesapeake Bay Program Phase 5 Model (CBP-P5) Land use class-definitions used for the Coastal Bays Watershed simulation

CBP-P5 Category	Land use definition	CBP-P5 Category	Land use definition
FOR	forest	PAS	pasture
NHI	nutrient management high-til with manure	NHO	nutrient management high-til without manure
PER	pervious urban	IMP	impervious urban
NHY	nutrient management hay	NLO	nutrient management low-til
BAR	construction	AFO	animal feeding operations
HYW	hay with nutrients		

The land use categories simulated by the HSPF model were derived from the original sources to reflect similar land use categories as those in the CBP-P5 (Table 7). The agriculture category from the reclassification of Worcester Co. data in Table 2, (HSPF_ID = 3), was later disaggregated into subcategories to match the simulated crops of the CBP-P5. The following procedure was applied: Multiplication factors to determine the individual crop categories in the Coastal Bays model were derived from the CBP-P5. These multiplication factors were simply the contribution of the individual crops to the agriculture category by county. For each of the individual sources of land use information (NLCD and Worcester County) the agricultural land use categories were aggregated; the aggregated value was later multiplied by the CBP-P5 multiplication factors to obtain the individual crop types.

The aggregated land use categories for the Coastal Bays model are shown in Figure 3. For data management purposes, the impervious categories were grouped into a single impervious category while the two previous categories were also grouped into a single pervious category. The final model simulates nine (9) pervious land use categories, one (1) impervious urban category, and one (1) category simulating feedlots.

Figure 3 presents the distribution the combined land uses in the Coastal Bays watershed. Table 8 presents the combined land use acres by subwatershed. The land use acreage of the watersheds used for model calibration (Birch Branch and Bassett Creek) is shown in Table 9. Figure 4 shows the relative amounts of different land uses in the watersheds draining into the Coastal Bays.

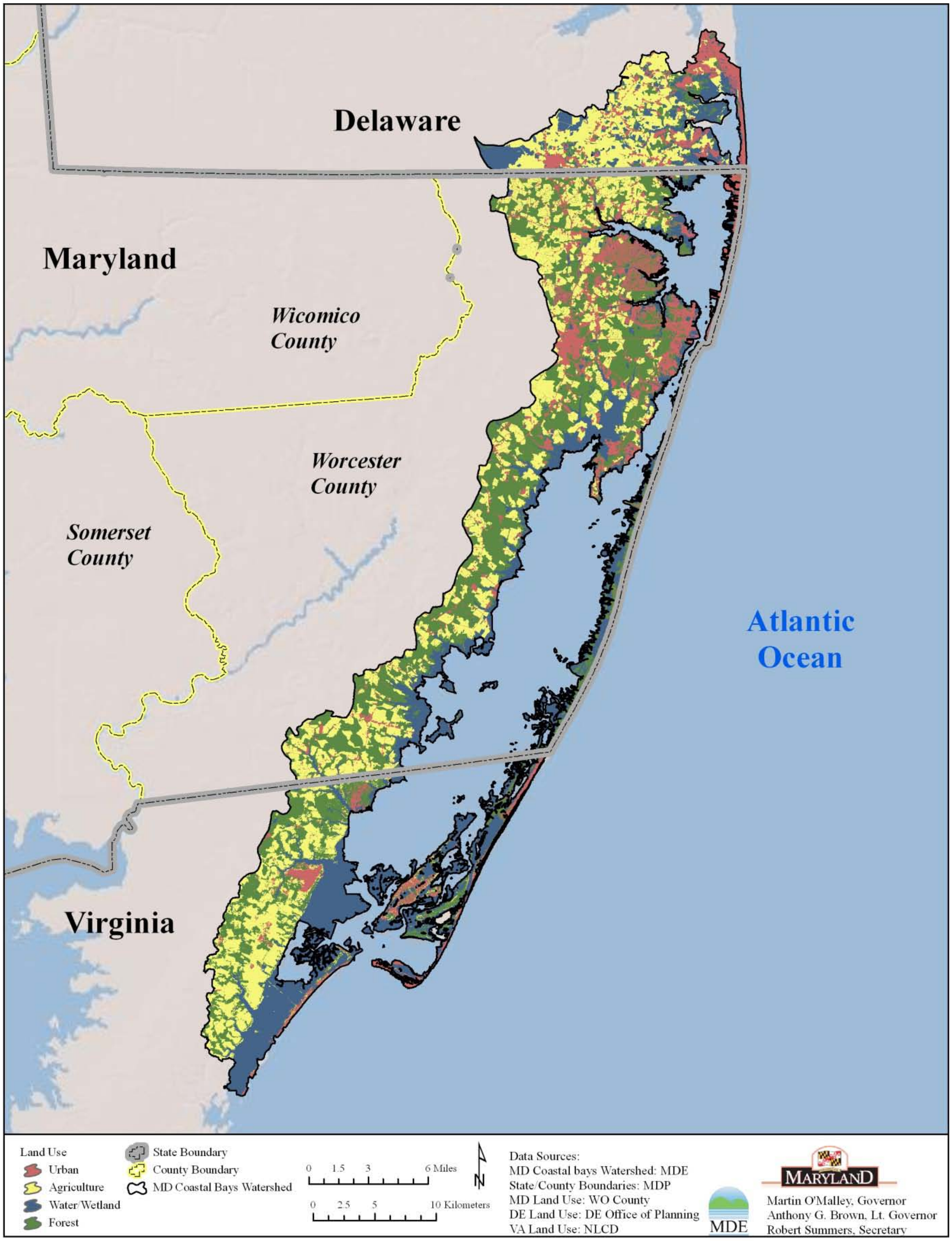

Figure 3. Land use distribution by subwatershed for the Coastal Bays HSPF watershed model.

Table 8. Land use by subwatershed for the Coastal Bays HSPF watershed model (acres).

	Assawoman Bay	Isle of Wight Bay	Sinepuxent Bay	Newport Bay	Chincoteague Bay
FOREST	4350.53	12921.60	2340.34	11641.21	31565.53
NHI	2055.03	2368.97	91.78	1398.81	4090.40
NHO	346.23	399.12	15.46	235.67	689.14
NHY	223.37	257.50	9.98	152.04	444.61
NLO	7974.40	9192.64	356.16	5427.99	15872.51
HYW	569.60	656.62	25.44	387.71	1133.75
PAS	306.63	194.31	0.00	32.26	4850.05
BAR	596.51	823.70	883.99	328.58	3891.35
PERVIOUS	5369.82	6073.28	1335.42	2873.86	3281.46
AFO	594.31	134.57	0.00	0.00	28.61
IMPERVIOUS	1468.38	3164.36	502.32	1034.48	757.40
WATER	7766.41	4874.85	1881.66	4869.30	34963.44

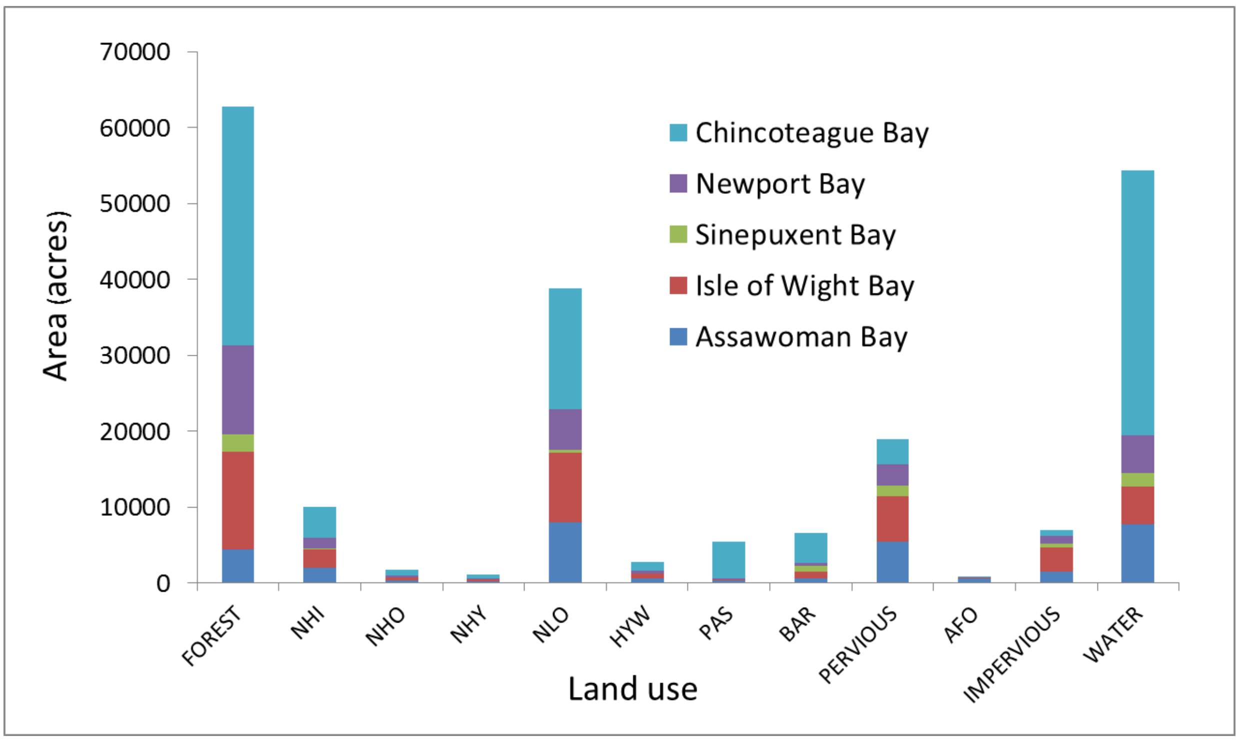

Figure 4. Relative amounts of the different land uses in the watersheds draining to the Maryland Coastal Bays

Table 9. Land use categories and number of acres for the calibrated watersheds: Birch Branch and Bassett Creek.

	FOR	NHI	NHO	NHY	NLO	HYW	PAS	BAR	PERV	Feetlots	IMP
Birch Branch	1896.5	312.4	52.6	34.0	1212.3	86.6	37.8	0.0	210.4	16.7	117.4
Bassett Creek	206.32	132.56	22.33	14.41	514.41	36.74	0.00	0.0	14.97	0.00	16.90

As presented above, the land use in the Coastal Bays watershed is diverse. The land cover consists of forest, agriculture, wetlands, and urban land uses. The land uses in the watershed consist of forest and other herbaceous growth (62,819 acres or 30%), mixed agriculture (60,515 acres or 29%), water (54,355 acres or 26%), urban (25,860 acres or 12%) and barren or beaches (6,524 acres or 3%).

5.0 Non-point Sources

5.1 Nutrient Application Rates and Nutrient Uptake

The nutrient application rates for land segment A24047 of the Chesapeake Bay Program Phase 5 Community Watershed Model (CBP-P5), which corresponds to Worcester County (2000 and 2002), were obtained from the USEPA-Chesapeake Bay Program Office. These values are shown in Table 10. The county-level agricultural census was used for the development of this information. For detailed documentation, see the U.S. EPA Chesapeake Bay Phase 5 Community Watershed Model.

Table 10. Nutrient applications, yields, and target uptakes for agricultural land uses. Source: U.S. EPA – CBP-P5.

Land Use	TN	TP	TN	TP	TN	TP
	Applications (lbs/acre/year)		Yield (lbs/acre/year)		Update Targets (lbs/acre/year)	
NHI	141.1	50.7	160.20	28.99	111.58	16.08
NHO	145.1	32.7	127.60	25.31	89.62	25.16
NHY	114.9	42.8	134.00	11.08	116.38	9.4
NLO	141.1	50.7	127.20	25.99	111.58	16.08
HYW	108.9	13.5	112.30	21.08	93.10	9.4

5.2 Animal Counts, Animal Units, and the Manure Land-Use Category

MDE estimated the number of chickens and horses by model segment using agriculture census and land use/land cover information. To normalize the amount of manure produced by each animal species, animal units were used. One animal unit is equivalent to the waste produced by one dairy cow. To estimate the amount of manure produced, MDE used a similar method as was used in the Delaware Inland Bays model developed by the USGS, DNREC and Delaware Geological Society in 2003. With this information, the recommended nutrient application rate for the individual crops was calculated following the procedures used in the CBP-P5. For cases in which the amount of manure was not enough to satisfy the recommended nutrient application rate, mineral fertilizer was used to supplement the application. The maximum nutrient application was restricted to 5 tons-application per acre based on the documented information in the report by Parker and Li (2006). Table 11 presents the assumptions used to calculate these loads and Table 12 presents the loads for poultry manure.

Table 11. Assumptions used to calculate poultry manure production.

Average Mass of Broiler Chicken at time of sale (lbs)	Total nitrogen loading rate (lbs/animal unit/year) after losses*
6.5 lbs	241.0
Chicken mass/Animal unit (lbs)	Total phosphorus loading rate (lbs/animal unit/year) after losses*
1000	99.0

*USDA NRCS, 2000.

Table 12. Loading represented by poultry manure. Poultry loads produced per identified watershed segment and associated delivered loads. Poultry calculated using 2002 Agriculture Census and 2002 MDP land use, 2002 Delaware Office of Planning and 2002 NLCD data.

SEGMENT	STATE	Area (acres)	Chickens (#)	Total Mass (lbs/yr)	TN Load Produced (lbs)	TP Load Produced (lbs)	TN Load applied to farm where produced (lbs)	TP Load applied to farm where produced (lbs)	TN Surplus (lbs)	TP Surplus (lbs)	TN Surplus Shipped Out (lbs)	TP Surplus Shipped Out (lbs)	TN Surplus distributed to adjacent farms within the segment (lbs)	TP Surplus distributed to adjacent farms within the segment (lbs)	TN Load Applied to the segment (lbs)	TP Load Applied to the segment (lbs)	TN Unit Load (lbs/acre)	TP Unit Load (lbs/acre)
1	MD	1452	25306	164492	39643	16285	13280	5455	26362	10829	8436	3465	17926	7364	48079	19750	33.103	13.598
2	MD	537	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
3	MD	98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
4	MD	109	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
5	MD	229	36364	236365	56964	23400	19083	7839	37881	15561	12122	4980	25759	10582	69086	28380	301.233	123.743
6	MD/DE	1100	44085	286553	69059	28369	23135	9504	45924	18865	14696	6037	31229	12828	54363	22332	49.424	20.303
7	DE	588	49446	321398	77457	31818	25948	10659	51509	21159	16483	6771	35026	14388	60974	25047	103.636	42.572
8	DE	722	22860	148591	35810	14710	11996	4928	23814	9782	7620	3130	16193	6652	28190	11580	39.018	16.028
9	MD/DE	311	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
10	MD/DE	428	50784	330093	79552	32679	26650	10948	52902	21732	16929	6954	35974	14778	96481	39633	225.249	92.530
11	MD/DE	86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
12	MD/DE	171	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
13	MD/DE	2828	644047	4186303	1008899	414444	337981	138839	670918	275605	214694	88194	456224	187412	1223593	502638	432.626	177.718
14	MD	113	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
15	MD	346	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
16	MD	1318	95130	618344	149021	61216	49922	20507	99099	40709	31712	13027	67387	27682	180732	74243	137.158	56.343
18	MD	118	64182	417181	100541	41301	33681	13836	66859	27465	21395	8789	45464	18676	121936	50090	1033.249	424.447
19	MD	351	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
20	MD	284	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
21	MD	265	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
22	MD	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
23	MD	408	21868	142145	34257	14072	11476	4714	22781	9358	7290	2995	15491	6364	41547	17067	101.836	41.833
24	MD	318	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
25	MD	467	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
26	MD	189	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
27	MD	154	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
28	MD	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
29	MD	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
30	MD	163	45822	297842	71780	29486	24046	9878	47734	19608	15275	6275	32459	13334	87055	35761	533.696	219.236
31	MD	459	114443	743877	179274	73644	60057	24671	119217	48973	38150	15671	81068	33302	217424	89315	473.878	194.664
32	MD	840	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
33	MD	538	56348	366262	88269	36260	29570	12147	58699	24113	18784	7716	39915	16397	107053	43976	198.899	81.705
34	MD	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000

SEGMENT	STATE	Area (acres)	Chickens (#)	Total Mass (lbs/yr)	TN Load Produced (lbs)	TP Load Produced (lbs)	TN Load applied to farm where produced (lbs)	TP Load applied to farm where produced (lbs)	TN Surplus (lbs)	TP Surplus (lbs)	TN Surplus Shipped Out (lbs)	TP Surplus Shipped Out (lbs)	TN Surplus distributed to adjacent farms within the segment (lbs)	TP Surplus distributed to adjacent farms within the segment (lbs)	TN Load Applied to the segment (lbs)	TP Load Applied to the segment (lbs)	TN Unit Load (lbs/acre)	TP Unit Load (lbs/acre)
35	MD	133	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
36	MD	280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
37	MD	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
38	MD	1667	35790	232634	56065	23031	18782	7715	37283	15315	11931	4901	25353	10415	67995	27932	40.788	16.755
39	MD	229	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
40	MD	86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
41	MD	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
42	MD	329	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
43	MD	76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
44	MD	2791	252606	1641938	395707	162552	132562	54455	263145	108097	84206	34591	178939	73506	479914	197143	171.931	70.627
45	MD	343	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
46	MD	452	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
47	MD	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
48	MD	169	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
49	MD	92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
50	MD	532	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
51	MD	2030	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
52	MD	178	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
53	MD	85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
54	MD	233	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
55	MD	59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
56	MD	209	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
57	MD	266	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
58	MD	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
59	MD	221	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
60	MD	176	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
61	MD	503	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
62	MD	280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
63	MD	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
64	MD	754	19293	125407	30223	12415	10125	4159	20098	8256	6431	2642	13667	5614	36654	15057	48.597	19.963
65	MD	65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
66	MD	251	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
67	MD	466	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
68	MD	110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
69	MD	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
70	MD	245	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
71	MD	877	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
72	MD	284	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
73	MD	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000

SEGMENT	STATE	Area (acres)	Chickens (#)	Total Mass (lbs/yr)	TN Load Produced (lbs)	TP Load Produced (lbs)	TN Load applied to farm where produced (lbs)	TP Load applied to farm where produced (lbs)	TN Surplus (lbs)	TP Surplus (lbs)	TN Surplus Shipped Out (lbs)	TP Surplus Shipped Out (lbs)	TN Surplus distributed to adjacent farms within the segment (lbs)	TP Surplus distributed to adjacent farms within the segment (lbs)	TN Load Applied to the segment (lbs)	TP Load Applied to the segment (lbs)	TN Unit Load (lbs/acre)	TP Unit Load (lbs/acre)
74	MD	463	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
75	MD	518	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
76	MD	11814	344287	2237867	539326	221549	180674	74219	358652	147330	114769	47146	243883	100184	654094	268694	55.368	22.744
77	MD	3868	56275	365789	88155	36213	29532	12131	58623	24082	18759	7706	39864	16376	106915	43919	27.641	11.355
78	MD	225	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
79	MD	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
80	MD	1813	27902	181364	43709	17955	14642	6015	29066	11940	9301	3821	19765	8119	53010	21776	29.241	12.012
81	MD	360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
82	MD	4613	176341	1146218	276238	113476	92540	38014	183699	75461	58784	24148	124915	51314	335022	137623	72.622	29.832
83	MD	403	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
84	MD	273	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
85	MD	742	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
86	MD	1373	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
87	MD	545	23871	155162	37394	15361	12527	5146	24867	10215	7957	3269	16910	6946	45351	18630	83.234	34.192
88	MD	167	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
89	MD	163	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
90	MD	2374	103366	671880	161923	66516	54244	22283	107679	44233	34457	14155	73222	30079	196380	80671	82.719	33.980
91	MD	693	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
92	MD	1626	45184	293695	70780	29076	23711	9740	47069	19335	15062	6187	32007	13148	85843	35263	52.788	21.685
93	MD	1892	69971	454810	109609	45026	36719	15084	72890	29942	23325	9582	49565	20361	132934	54608	70.267	28.865
94	MD	221	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
95	MD	1936	42440	275862	66483	27310	22272	9149	44211	18161	14148	5812	30063	12350	80630	33122	41.638	17.104
96	MD	550	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
97	MD	201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
98	MD	154	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
99	MD	530	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
100	MD	465	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
101	MD	1206	52230	339496	81819	33610	27409	11259	54409	22351	17411	7152	36998	15198	99230	40762	82.288	33.803
102	MD	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
103	MD	334	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
104	MD	270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
105	MD	237	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
106	MD	1367	26733	173764	41877	17203	14029	5763	27848	11440	8911	3661	18937	7779	50789	20863	37.145	15.259
107	MD	1695	57448	373410	89992	36968	30147	12384	59845	24583	19150	7867	40694	16717	109142	44834	64.407	26.457
108	MD	4010	287934	1871570	451048	185285	151101	62071	299947	123215	95983	39429	203964	83786	547032	224714	136.424	56.041
109	MD	201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
110	MD	213	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
111	MD	537	31947	207656	50045	20558	16765	6887	33280	13671	10650	4375	22630	9296	60695	24933	113.102	46.461
112	MD	83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000

SEGMENT	STATE	Area (acres)	Chickens (#)	Total Mass (lbs/yr)	TN Load Produced (lbs)	TP Load Produced (lbs)	TN Load applied to farm where produced (lbs)	TP Load applied to farm where produced (lbs)	TN Surplus (lbs)	TP Surplus (lbs)	TN Surplus Shipped Out (lbs)	TP Surplus Shipped Out (lbs)	TN Surplus distributed to adjacent farms within the segment (lbs)	TP Surplus distributed to adjacent farms within the segment (lbs)	TN Load Applied to the segment (lbs)	TP Load Applied to the segment (lbs)	TN Unit Load (lbs/acre)	TP Unit Load (lbs/acre)
113	MD	1368	77270	502256	121044	49723	40550	16657	80494	33066	25758	10581	54736	22485	146802	60304	107.341	44.095
114	MD	861	25155	163507	39405	16187	13201	5423	26204	10764	8385	3445	17819	7320	47791	19632	55.485	22.792
115	MD	221	28416	184704	44514	18286	14912	6126	29602	12160	9473	3891	20129	8269	53986	22177	243.951	100.212
116	MD/VA	556	14000	91000	21931	9009	7347	3018	14584	5991	4667	1917	9917	4074	17264	7092	31.028	12.746
117	MD/VA	761	14000	91000	21931	9009	7347	3018	14584	5991	4667	1917	9917	4074	26598	10926	34.932	14.350
118	MD/VA	1126	24989	162427	39145	16080	13114	5387	26031	10693	8330	3422	17701	7271	47475	19502	42.147	17.313
119	VA	223	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
120	MD/VA	9805	273554	1778103	428523	176032	143555	58971	284968	117061	91190	37460	193778	79602	519712	213492	53.003	21.773
121	VA	139	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
122	VA	642	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
123	VA	1193	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
124	VA	358	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
125	VA	249	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
126	VA	212	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
127	VA	178	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
128	VA	186	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
129	VA	14176	160500	1043250	251423	103282	84227	34599	167196	68682	53503	21978	113694	46704	197920	81303	13.961	5.735
130	VA	1193	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
131	VA	355	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
132	VA	411	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
133	VA	914	345600	2246400	541382	222394	181363	74502	360019	147892	115206	47325	244813	100566	426176	175068	466.282	191.543
134	VA	275	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
135	VA	441	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
136	VA	359	412000	2678000	645398	265122	216208	88816	429190	176306	137341	56418	291849	119888	508057	208704	1413.737	580.747
137	VA	278	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
138	VA	514	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
139	VA	1554	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
140	VA	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
141	VA	10591	752000	4888000	1178008	483912	394633	162111	783375	321801	250680	102976	532695	218825	927328	380936	87.556	35.967
142	VA	4737	120000	780000	187980	77220	62973	25869	125007	51351	40002	16432	85005	34919	147978	60788	31.237	12.832
143	MD	963	14432	93806	22607	9287	7573	3111	15034	6176	4811	1976	10223	4199	27418	11263	28.459	11.691
144	MD	4019	782021	5083136	1225036	503230	410387	168582	814649	334648	260688	107087	553961	227561	1485723	610318	369.706	151.871
145	MD	2405	132324	860103	207285	85150	69440	28525	137844	56625	44110	18120	93734	38505	251395	103270	104.529	42.939
146	MD	231	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
147	MD	115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000

SEGMENT	STATE	Area (acres)	Chickens (#)	Total Mass (lbs/yr)	TN Load Produced (lbs)	TP Load Produced (lbs)	TN Load applied to farm where produced (lbs)	TP Load applied to farm where produced (lbs)	TN Surplus (lbs)	TP Surplus (lbs)	TN Surplus Shipped Out (lbs)	TP Surplus Shipped Out (lbs)	TN Surplus distributed to adjacent farms within the segment (lbs)	TP Surplus distributed to adjacent farms within the segment (lbs)	TN Load Applied to the segment (lbs)	TP Load Applied to the segment (lbs)	TN Unit Load (lbs/acre)	TP Unit Load (lbs/acre)
148	MD/DE	103	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
149	MD	241	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
150	MD	195	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
151	MD	151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
152	MD	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
153	MD	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
154	MD	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
155	MD	83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
156	MD	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
157	MD	58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
158	MD	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
159	MD	273	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
160	MD	288	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
161	MD	204	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
162	MD	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
163	MD	91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
164	MD	97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
165	MD	102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
166	MD	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
167	MD	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
168	MD	158	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
169	MD	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
170	MD	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
171	MD	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
172	MD	95	37497	243730	58739	24129	19678	8083	39061	16046	12500	5135	26562	10911	71238	29264	748.888	307.634
173	MD	174	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
174	MD	108	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
175	MD	265	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
176	MD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
177	MD	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
179	MD	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
180	MD	134	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
181	MD	408	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
182	MD	74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
183	MD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
184	MD	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
185	VA	119	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000

SEGMENT	STATE	Area (acres)	Chickens (#)	Total Mass (lbs/yr)	TN Load Produced (lbs)	TP Load Produced (lbs)	TN Load applied to farm where produced (lbs)	TP Load applied to farm where produced (lbs)	TN Surplus (lbs)	TP Surplus (lbs)	TN Surplus Shipped Out (lbs)	TP Surplus Shipped Out (lbs)	TN Surplus distributed to adjacent farms within the segment (lbs)	TP Surplus distributed to adjacent farms within the segment (lbs)	TN Load Applied to the segment (lbs)	TP Load Applied to the segment (lbs)	TN Unit Load (lbs/acre)	TP Unit Load (lbs/acre)
186	MD/DE	10651	1069808	6953749	1675854	688421	561411	230621	1114443	457800	356622	146496	757821	311304	2032475	834917	190.823	78.388
187	MD	6164	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
235	MD	2590	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
236	MD	1835	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
237	MD	557	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
238	MD	103	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
239	MD	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
240	VA	5019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
241	VA	7871	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
242	VA	1014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
254	VA	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
255	VA	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
256	VA	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
257	VA	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
259	VA	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
260	VA	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
261	VA	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
263	VA	168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
264	VA	192	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
265	VA	142	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
330	DE	1590	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
350	DE	2257	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
360	DE	4383	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
370	DE	7066	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
380	DE	872	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
410	DE	2640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
440	DE	1401	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
500	MD	6988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
510	MD	1031	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000
520	MD	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000

5.3 Atmospheric Deposition

Atmospheric deposition occurs when pollutants are transferred from the air to the earth's surface. In the watershed model, this load is simulated as part of the non-point source loads and it is applied as a time series to all the simulated land uses as well as the simulated streams for the calibrated segments (Birch Branch and Bassett Creek). The time series for the calibrated segments was obtained from the U.S. EPA - Chesapeake Bay Program Office (EPA-CBP). For detailed documentation, see the U.S. EPA's CBP-P5 Model. For the other segments within the watershed model, the loading rate for the land uses incorporates atmospheric deposition to that land use since the parameters were transferred from the calibrated segments to all other segments.

The time series for the Coastal Bays watershed and for the period of simulation was obtained from the National Atmospheric Deposition Program data collected at Assateague Island National Seashore for the period of 2001 – 2004. Only wet-deposited nitrogen is collected at the station, and it was assumed that dry-deposits of nitrogen are roughly the same; therefore, the deposition amount was doubled to account for both wet and dry conditions. In keeping with Chesapeake Bay TMDL/Community Multi-scale Air Quality Model methodology, a 20:1 nitrogen:phosphorus ratio was assumed to incorporate phosphorus deposition. The total atmospheric depositional loads to the water surface for the 8-digit basins are presented in Table 13.

Table 13. Atmospheric deposition loads by 8-digit watershed.

8-Digit Watershed	TN lbs/year	TP lbs/year
Assawoman Bay	63,362	3,167
Isle of Wight Bay	51,901	2,594
Newport Bay	30,214	1,510
Sinepuxent Bay	43,396	2,169
Chincoteague Bay	547,573	27,367
Total	736,446	36,807

5.4 On-site wastewater disposal system information

The average septic system delivers about 30 lbs. of nitrogen per year to the groundwater. Of the estimated 420,000 septic systems in Maryland, 52,000 septic systems are in the Critical Area (within 1000 feet of tidal waters of the State); approximately 80 percent of the nitrogen from a septic system in the Critical Area will reach surface waters (MDE, 2009). Therefore, septic loads are included as a source of nutrients within the watershed.

Septic load values were calculated using 2000 U.S. Census for Virginia's portion of the watershed, MDE's on-site disposal system point data (2007) for Worcester County, Chesapeake Bay Program Phase 5.3.2 Model sewer sheds, Delaware Department of Natural Resources and Environmental Control (DNREC) septic GIS point data (1997), and the HSPF watershed model segmentation by MDE. Assumptions used in the analysis are presented in Table 14. These loads were calculated based on a methodology used by the EPA-CBP. Table 15 presents the calculated septic loads for all segments.

Table 14. Assumptions used in the septic load analysis.

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

Table 15. Information used to estimate nitrogen septic loads and the delivered septic loads used in the VIMS hydrodynamic model by HSPF segment.

SEGMENT	*MD # Septics (within 1,000 ft)*	*MD # Septics (outside 1,000 ft)*	*VA/DE # Septics (within 1,000 ft)*	*VA/DE # Septics (outside 1,000 ft)*	*Total # Septics (within 1,000 ft)*	*Total # Septics (outside 1,000 ft)*	*Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/year)*	*Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/year)*	*Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/day)*	*Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/day)*	*Total Surface Water Delivered Nitrogen Load with Loss (lbs/day)*
1	95	6	0	0	95	6	2310	55	6.33	0.15	6.48
2	76	13	0	0	76	13	1848	119	5.06	0.32	5.39
3	1	1	0	0	1	1	24	9	0.07	0.02	0.09
4	3	2	0	0	3	2	73	18	0.20	0.05	0.25
5	36	0	0	0	36	0	876	0	2.40	0.00	2.40
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
21	0	2	0	0	0	2	0	18	0.00	0.05	0.05
22	2	0	0	0	2	0	49	0	0.13	0.00	0.13
23	3	11	0	0	3	11	73	100	0.20	0.27	0.47
24	18	7	0	0	18	7	438	64	1.20	0.17	1.37
27	3	0	0	0	3	0	73	0	0.20	0.00	0.20

SEGMENT	MD # Septics (within 1,000 ft)	MD # Septics (outside 1,000 ft)	VA/DE # Septics (within 1,000 ft)	VA/DE # Septics (outside 1,000 ft)	Total # Septics (within 1,000 ft)	Total # Septics (outside 1,000 ft)	Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/year)	Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/year)	Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/day)	Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/day)	Total Surface Water Delivered Nitrogen Load with Loss (lbs/day)
28	0	10	0	0	0	10	0	91	0.00	0.25	0.25
29	0	7	0	0	0	7	0	64	0.00	0.17	0.17
30	36	19	0	0	36	19	876	173	2.40	0.47	2.87
31	69	11	0	0	69	11	1678	100	4.60	0.27	4.87
32	11	1	0	0	11	1	268	9	0.73	0.02	0.76
33	11	26	0	0	11	26	268	237	0.73	0.65	1.38
34	6	0	0	0	6	0	146	0	0.40	0.00	0.40
37	1	0	0	0	1	0	24	0	0.07	0.00	0.07
38	8	116	0	0	8	116	195	1058	0.53	2.90	3.43
39	3	0	0	0	3	0	73	0	0.20	0.00	0.20
42	1	0	0	0	1	0	24	0	0.07	0.00	0.07
44	237	92	0	0	237	92	5764	839	15.79	2.30	18.09
45	25	1	0	0	25	1	608	9	1.67	0.02	1.69
46	36	0	0	0	36	0	876	0	2.40	0.00	2.40
49	17	0	0	0	17	0	413	0	1.13	0.00	1.13
50	0	1	0	0	0	1	0	9	0.00	0.02	0.02
51	75	11	0	0	75	11	1824	100	5.00	0.27	5.27
57	0	1	0	0	0	1	0	9	0.00	0.02	0.02
59	0	2	0	0	0	2	0	18	0.00	0.05	0.05
60	0	4	0	0	0	4	0	36	0.00	0.10	0.10
61	2	9	0	0	2	9	49	82	0.13	0.22	0.36
62	40	5	0	0	40	5	973	46	2.67	0.12	2.79
63	3	0	0	0	3	0	73	0	0.20	0.00	0.20
64	73	8	0	0	73	8	1775	73	4.86	0.20	5.06
65	1	0	0	0	1	0	24	0	0.07	0.00	0.07

SEGMENT	MD # Septics (within 1,000 ft)	MD # Septics (outside 1,000 ft)	VA/DE # Septics (within 1,000 ft)	VA/DE # Septics (outside 1,000 ft)	Total # Septics (within 1,000 ft)	Total # Septics (outside 1,000 ft)	Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/year)	Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/year)	Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/day)	Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/day)	Total Surface Water Delivered Nitrogen Load with Loss (lbs/day)
66	1	6	0	0	1	6	24	55	0.07	0.15	0.22
67	2	5	0	0	2	5	49	46	0.13	0.12	0.26
69	4	0	0	0	4	0	97	0	0.27	0.00	0.27
70	3	0	0	0	3	0	73	0	0.20	0.00	0.20
71	28	48	0	0	28	48	681	438	1.87	1.20	3.06
72	82	8	0	0	82	8	1994	73	5.46	0.20	5.66
73	7	3	0	0	7	3	170	27	0.47	0.07	0.54
74	24	3	0	0	24	3	584	27	1.60	0.07	1.67
75	4	0	0	0	4	0	97	0	0.27	0.00	0.27
76	366	160	0	0	366	160	8901	1459	24.39	4.00	28.38
77	124	63	0	0	124	63	3016	575	8.26	1.57	9.84
78	0	1	0	0	0	1	0	9	0.00	0.02	0.02
80	39	12	0	0	39	12	948	109	2.60	0.30	2.90
82	94	28	0	0	94	28	2286	255	6.26	0.70	6.96
83	2	0	0	0	2	0	49	0	0.13	0.00	0.13
85	6	3	0	0	6	3	146	27	0.40	0.07	0.47
86	8	10	0	0	8	10	195	91	0.53	0.25	0.78
87	0	1	0	0	0	1	0	9	0.00	0.02	0.02
88	4	0	0	0	4	0	97	0	0.27	0.00	0.27
89	0	1	0	0	0	1	0	9	0.00	0.02	0.02
90	16	8	0	0	16	8	389	73	1.07	0.20	1.27
92	10	9	0	0	10	9	243	82	0.67	0.22	0.89
93	35	19	0	0	35	19	851	173	2.33	0.47	2.81
94	4	0	0	0	4	0	97	0	0.27	0.00	0.27
95	33	5	0	0	33	5	803	46	2.20	0.12	2.32

SEGMENT	MD # Septics (within 1,000 ft)	MD # Septics (outside 1,000 ft)	VA/DE # Septics (within 1,000 ft)	VA/DE # Septics (outside 1,000 ft)	Total # Septics (within 1,000 ft)	Total # Septics (outside 1,000 ft)	Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/year)	Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/year)	Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/day)	Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/day)	Total Surface Water Delivered Nitrogen Load with Loss (lbs/day)
96	11	1	0	0	11	1	268	9	0.73	0.02	0.76
99	5	0	0	0	5	0	122	0	0.33	0.00	0.33
100	3	3	0	0	3	3	73	27	0.20	0.07	0.27
101	20	24	0	0	20	24	486	219	1.33	0.60	1.93
103	1	0	0	0	1	0	24	0	0.07	0.00	0.07
104	0	1	0	0	0	1	0	9	0.00	0.02	0.02
105	0	4	0	0	0	4	0	36	0.00	0.10	0.10
106	7	11	0	0	7	11	170	100	0.47	0.27	0.74
107	15	29	0	0	15	29	365	264	1.00	0.72	1.72
108	48	45	0	0	48	45	1167	410	3.20	1.12	4.32
111	4	35	0	0	4	35	97	319	0.27	0.87	1.14
112	0	4	0	0	0	4	0	36	0.00	0.10	0.10
113	69	11	0	0	69	11	1678	100	4.60	0.27	4.87
114	11	2	0	0	11	2	268	18	0.73	0.05	0.78
115	0	1	0	0	0	1	0	9	0.00	0.02	0.02
116	0	0	16	16	16	16	378	142	1.04	0.39	1.43
117	2	7	16	16	18	23	433	208	1.19	0.57	1.76
118	15	5	29	29	44	34	1081	314	2.96	0.86	3.82
119	0	0	12	12	12	12	304	114	0.83	0.31	1.14
120	72	16	175	175	247	191	5998	1739	16.43	4.76	21.20
121	0	0	8	8	8	8	189	71	0.52	0.19	0.71
122	0	0	36	36	36	36	874	328	2.40	0.90	3.29
123	0	0	67	67	67	67	1624	609	4.45	1.67	6.12
124	0	0	20	20	20	20	488	183	1.34	0.50	1.84
125	0	0	14	14	14	14	339	127	0.93	0.35	1.28

SEGMENT	MD # Septics (within 1,000 ft)	MD # Septics (outside 1,000 ft)	VA/DE # Septics (within 1,000 ft)	VA/DE # Septics (outside 1,000 ft)	Total # Septics (within 1,000 ft)	Total # Septics (outside 1,000 ft)	Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/year)	Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/year)	Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/day)	Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/day)	Total Surface Water Delivered Nitrogen Load with Loss (lbs/day)
126	0	0	12	12	12	12	288	108	0.79	0.30	1.09
128	0	0	10	10	10	10	245	92	0.67	0.25	0.92
129	0	0	533	533	533	533	12964	4861	35.52	13.32	48.84
130	0	0	20	20	20	20	480	180	1.31	0.49	1.81
131	0	0	6	6	6	6	143	53	0.39	0.15	0.54
132	0	0	7	7	7	7	165	62	0.45	0.17	0.62
133	0	0	15	15	15	15	368	138	1.01	0.38	1.38
134	0	0	5	5	5	5	111	41	0.30	0.11	0.42
135	0	0	7	7	7	7	177	66	0.49	0.18	0.67
136	0	0	6	6	6	6	144	54	0.40	0.15	0.54
137	0	0	5	5	5	5	112	42	0.31	0.11	0.42
138	0	0	9	9	9	9	207	78	0.57	0.21	0.78
139	0	0	26	26	26	26	625	234	1.71	0.64	2.35
140	0	0	2	2	2	2	40	15	0.11	0.04	0.15
141	0	0	182	182	182	182	4438	1664	12.16	4.56	16.72
142	0	0	92	92	92	92	2237	839	6.13	2.30	8.43
143	12	3	0	0	12	3	292	27	0.80	0.07	0.87
144	120	29	0	0	120	29	2918	264	8.00	0.72	8.72
145	61	14	0	0	61	14	1484	128	4.06	0.35	4.41
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
154	1	0	0	0	1	0	24	0	0.07	0.00	0.07
155	3	1	0	0	3	1	73	9	0.20	0.02	0.22
156	42	0	0	0	42	0	1021	0	2.80	0.00	2.80

SEGMENT	***MD # Septics (within 1,000 ft)***	***MD # Septics (outside 1,000 ft)***	***VA/DE # Septics (within 1,000 ft)***	***VA/DE # Septics (outside 1,000 ft)***	***Total # Septics (within 1,000 ft)***	***Total # Septics (outside 1,000 ft)***	***Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/year)***	***Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/year)***	***Total Surface Water Delivered Nitrogen Load with Loss (Within 1,000 ft) (lbs/day)***	***Total Surface Water Delivered Nitrogen Load with Loss (Outside 1,000 ft) (lbs/day)***	***Total Surface Water Delivered Nitrogen Load with Loss (lbs/day)***
157	5	0	0	0	5	0	122	0	0.33	0.00	0.33
160	1	0	0	0	1	0	24	0	0.07	0.00	0.07
161	47	0	0	0	47	0	1143	0	3.13	0.00	3.13
163	11	0	0	0	11	0	268	0	0.73	0.00	0.73
167	1	0	0	0	1	0	24	0	0.07	0.00	0.07
172	2	0	0	0	2	0	49	0	0.13	0.00	0.13
174	8	0	0	0	8	0	195	0	0.53	0.00	0.53
175	30	1	0	0	30	1	730	9	2.00	0.02	2.02
179	1	0	0	0	1	0	24	0	0.07	0.00	0.07
180	38	0	0	0	38	0	924	0	2.53	0.00	2.53
184	3	0	0	0	3	0	73	0	0.20	0.00	0.20
185	0	0	7	7	7	7	163	61	0.45	0.17	0.61
186	239	48	0	292	239	340	5812	3101	15.92	8.50	24.42
187	107	42	0	0	107	42	2602	383	7.13	1.05	8.18
235	2	0	0	0	2	0	49	0	0.13	0.00	0.13
237	1	0	0	0	1	0	24	0	0.07	0.00	0.07
239	1	0	0	0	1	0	24	0	0.07	0.00	0.07
240	0	0	647	647	647	647	15731	5899	43.10	16.16	59.26
241	0	0	210	210	210	210	5097	1911	13.96	5.24	19.20
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

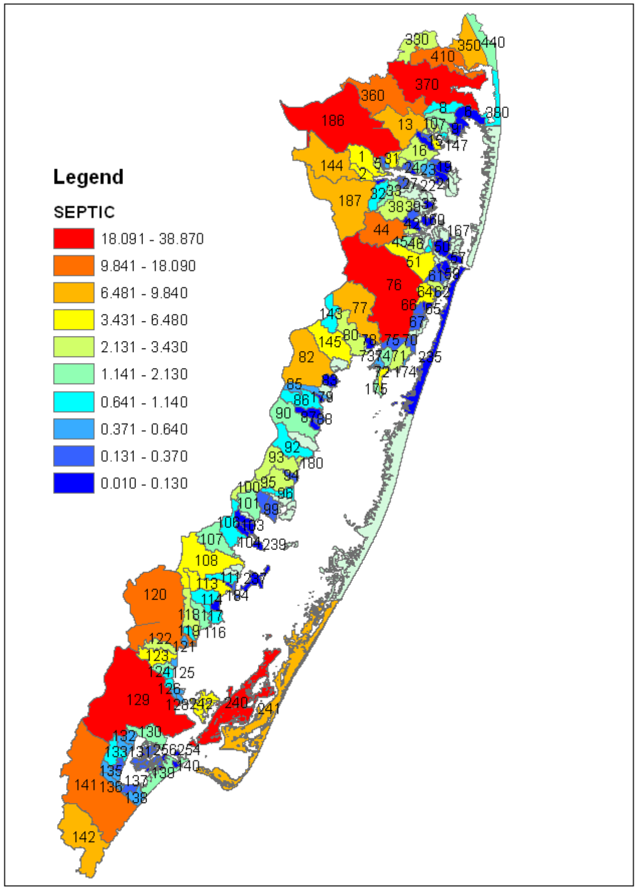

Figure 5. The distribution of septic nitrogen loads (pounds/day) in the Maryland Coastal Bays Watershed.

For modeling purposes, septic loads (Figure 5) were applied as a non-point source load from the watershed model, which are discharged to the SELFE hydrodynamic model in the Coastal Bay.

6.0 Point sources

Point sources are discharges that can be traced back to the end of a pipe. Point sources were not included in the watershed model as no waste water treatment plants are located in Birch Branch or Bassett Creek watershed model segments. Additional point sources were included in the water quality model. The data for these facilities are displayed in Tables 16-20.

6.1 Delivered Loads by Source

Table 16. Spray Irrigation Facility delivered loads. The delivered loads account for plant uptake and proximity to the stream reach.

Model Segment	**MDE Permit #**	**Facility Name**	**Irrigation Field/Season**[1]	**Design Flow** (gpd)[2]	**TN** (mg/l)[3]	**Delivered Load** (lbs)
45	01DP2710B	Riddle Farm WWTP	Outfall 001 (Undeveloped Tract 1: 13 acres) - Growing Season (March-October)	57600	5	0
45	01DP2710B	Riddle Farm WWTP	Outfall 002 (Golf Course and Undeveloped Tract 2: 136.6 acres) - Growing Season (March-October)	197750	5	0
150	01DP3155	Lighthouse Sound WWTP	Golf Course and Wooded Undeveloped Tract: 32.7 acres - Growing Season (March-October)	37950	12	0
150	01DP3155	Lighthouse Sound WWTP	Golf Course and Wooded Undeveloped Tract: 32.7 acres - Non-Growing Season (2/4 months)	37950	12	183.13
64	06DP2608	Assateague Pointe WWTP	Spray Irrigation Field: 9.2 acres - Growing Season (March-October)	41930	10	252.93
64	06DP2608	Assateague Pointe WWTP	Spray Irrigation Field: 9.2 acres - Non-Growing Season (2/4 months)	41930	18	113.81
32	99-DP-2394	River Run WWTP	Spray Irrigation Field: 23.2 acres - Growing Season (March-October)	112070	10	1802.64
32	99-DP-2394	River Run WWTP	Spray Irrigation Field: 23.2 acres - Non-Growing Season (2/4 months)	112070	18	811.19
186	99-DP-0814	Perdue Farms	Spray Irrigation Field: 6 acres - Growing Season (March-October)	3800	N/A	434.12
186	99-DP-0814	Perdue Farms	Spray Irrigation Field: 6 acres - Non-Growing Season (2/4 months)	3800	N/A	113.40

Table 17. Injection Well Delivered Loads.

						TN Delivered Load (lbs/day)
WS-model segment	**MDE Permit #**	**Facility Name**	**Flow(mgd)**	**TN(mg/l)**	**Load (lbs/day)**	**net surface water load(lbs/day)**
59	04DP2273	The Mystic Harbour	0.25	3.00	6.26	6.26
64	08DP0121	The Landings	0.10	10.00	8.34	2.50

Table 18. Maryland Point Sources

WS-model segment	MDE Permit #	NPDES #	Facility Name	Period	Flow mgd	TN mg/l	TP mg/l	TKN mg/l	NH3 mg/l	TN Load (lbs/yr)	TP Load (lb/yr)
Industrial Facilities											
187	95DP0051A	MD0000965	Perdue Farm, Inc. -Showell Complex	May-Oct	0.8	5	0.5		2	12176.4	1217.64
				Nov-Apr	0.8	5	0.5		5		
76	01DP0266	MD0001309	Kelly Foods Corporation	May-Sep	0.02	18	0.6	10		1095.88	36.5292
				Oct-Apr	0.02	18	0.6				
76	96DP0375	MD0002071	Berlin Properties North, LLC (Hudson/Tyson Foods Inc.)	May-Oct	0.8	4	0.5	4	2	9741.12	1217.64
				Nov-Apr	0.8	4	0.5		5		
Municipal Facilities											
36	05DP0708	MD0023477	Ocean Pines WWTP	May-Oct	2.5	3	1.2			72,162	9,132
				Nov-Apr	2.5	16	1.2				
174	05DP2530	MD0021091	Assateague Island National Seashore WWTP	Jan-Dec	0.012	3	0.3			110	11
76	98DP0669	MD0022632	Berlin WWTP	Apr-Oct	0	0	0			3,378	375
				Nov-Mar	0.6	4.5	0.5		0.5		
82	05DP0141	MD0020630	Newark WWTP	Apr-Oct	0.07	18	3	8	2.3	3,836	639
				Nov-Mar	0.07	18	3	8	7.1		
outside	05DP0596	MD0020044	Ocean City WWTP	Jan-Dec	14	18	3			767,113	127,852

Table 19. Virginia Municipal WWTP Delivered Loads

NPDES #	**Facility Name**[1]	**Major/ Minor**	**Type**	**SIC Code**	**SIC Name**	**Outfall**	**Design Flow** (mgd)	**Estimated Avg. TN Conc.** (mg/l)	**Estimated Avg. TP Conc.** (mg/l)	**TN Limit** (mg/l)	**TP Limit** (mg/l)	**TN Load** (lbs/yr)	**TP Load** (lbs/yr)
VA0024 457	US NASA - Wallops Flight Facility[2]	MINOR	Municipal	3769	Guided Missile and Space Vehicle Parts and Auxiliary Equipment	001	0.3	18.7	2.5	18.7	2.5	17154. 3	2293.4
VA0054 003	Sunset Bay Utilities - South[3]	MINOR	Municipal	5812	Eating Places	001	0.0395	20.0	15.0	20.0	15.0	2415.7	1811.8
VA0087 327	US Coast Guard Group - Eastern Shore[2]	MINOR	Municipal	9621	Regulation and Administration of Transportation Programs	001	0.006	18.7	2.5	18.7	2.5	343.1	45.9
VA0089 265	Comfort Suites Hotel - Chincoteague[3]	MINOR	Municipal	7011	Hotels and Motels	001	0.009	20.0	15.0	20.0	15.0	550.4	412.8
VA0090 506	Hampton Inn and Suites[3]	MINOR	Municipal	7011	Hotels and Motels	001	0.01	20.0	15.0	20.0	15.0	611.6	458.7
VA0091 049	Sunset Bay Utilities - North[3]	MINOR	Municipal	8811	Private Households	001	0.025	20.0	15.0	20.0	15.0	1528.9	1146.7
VA0091 618	Chincoteague Landmark WWTP[4]	MINOR	Municipal	4952	Sewerage Systems	001	0.035	18.7	2.5	18.7	2.5	2001.3	267.6
VA0091 677	Taylor Landing[3]	MINOR	Municipal	7011	Hotels and Motels	001	0.012	20.0	15.0	20.0	15.0	733.9	550.4
VA0092 037	Rays Shanty[3,5]	MINOR	Municipal	5812	Eating Places	001	0.0191	20.0	15.0	20.0	15.0	1168.1	876.1

Notes:
[1]Chincoteague Town WTP was eliminated from the analysis since it is a water supply, surface water discharge permit. Therefore, TN/TP concentrations are expected to be de minimis. Only TSS concentrations from the discharge would be of any significance.
[2]US NASA Wallops Flight Facility and US Coast Guard Group - Eastern are both federal facilities. TN/TP concentrations were estimated based on descriptions of the type of wastewater treatment at the facilities found in a spreadsheet of southeast Virginia treatment plants on VADEQ's website. Outfall 002 at US NASA Wallops Island did not need to be included in the analysis, since the discharge has been inactive since 1993, well before the model calibration time period.
[3]Estimated TN/TP concentrations associated with the wastewater treatment at these hotels/motels and eateries is based on monitored concentrations at similar facilities in Maryland.
[4]Estimated TN/TP concentrations associated with the municipal, sewered WWTP is based on Virginia's default Bay Phase I WIP value used for minor municipal facilities in order to characterize the loadings from these facilities, if they were missing data.
[5]The Design Flow for Ray's Shanty was missing from the Accomak County 2008 Comprehensive Plan Update, which was used to gather the design flows for all of the other facilities. Therefore, to estimate a flow for the facility, the average flow of the other hotel/motel and eatery facilities was applied.
[6]Average TKN weekly and monthly limits are identified within the actual permits for the facilities; however, no TN or TP limits are specified.

Table 20. Delaware Point Source Information

Facility	**TN Load** (lbs/y)	**TP Load** (lbs/y)
Mountaire Selbyville Poultry Processing Facility - Chicken Holding Area (Outfall 002)	2359	483.9
Notes:		
[1]John Defriece of DNREC estimated the TN and TP loads entering Outfall 002 based on an extrapolation of the annual DMR TN/TP concentrations and flow data to rainfall data over the same time period and the Outfall 002 drainage area.		
[2]No delivery factor assumed, since we have no means of estimating attenuation within the dry ditch and grass swale that carry the runoff from the holding area to the receiving stream.		

7.0 Meteorological Data

7.1 Rainfall Cross-Correlation Analyses for the Allocation of Precipitation to Model Segments

Rainfall data provide the forcing function of an HSPF model. However, the availability of complete records on any site in which rainfall depth is measured varies greatly. Six rainfall records (Figure 6) were available in the area of the project: (1) daily records provided by staff of the Selbyville (SV) Waste Water Treatment Plant ((WWTP) – personal communication); (2) Ocean City Municipal Airport, station NCDC 93786 (OC); (3) Snow Hill (SH), COOP ID 188380; (4) sparse daily records from Assateague Island (AI) COOP ID 180335 ; (5) Wallops Island (WA), station NCDC 72402; and (5) the Chesapeake Bay P5-derived data (CBP-P5) for Worcester County. While the rainfall records from SV, OC, SH, AI, and WA were measured at individual sites, the records from CB are derived values from a mathematical model developed by the USGS (Hay et al., 1991, 2000a, 2000b). The CBP-P5 records consisted of hourly depths for each hour of the calibration period. Records from Snow Hill were not used because the station was located outside of the Coastal Bays watershed and because a complete set of data was not available for the period of simulation. Records from Assateague Island were not used because the records were also incomplete and at a daily time step. Rainfall stations were mapped to the watershed segment based on the distances (MDE and UMCP, 2010).

Hourly precipitation data from the Ocean City Municipal Airport station were used for both Birch Branch and Bassett Creek watershed model simulations. Data from Wallops Island were assigned to the southernmost segments of the watershed while Selbyville daily precipitation data were used to extend the period of simulation of the Delaware Inland Bays Watershed model. Daily records from Selbyville WWTP were disaggregated to hourly values and applied to the model segments located in Delaware.

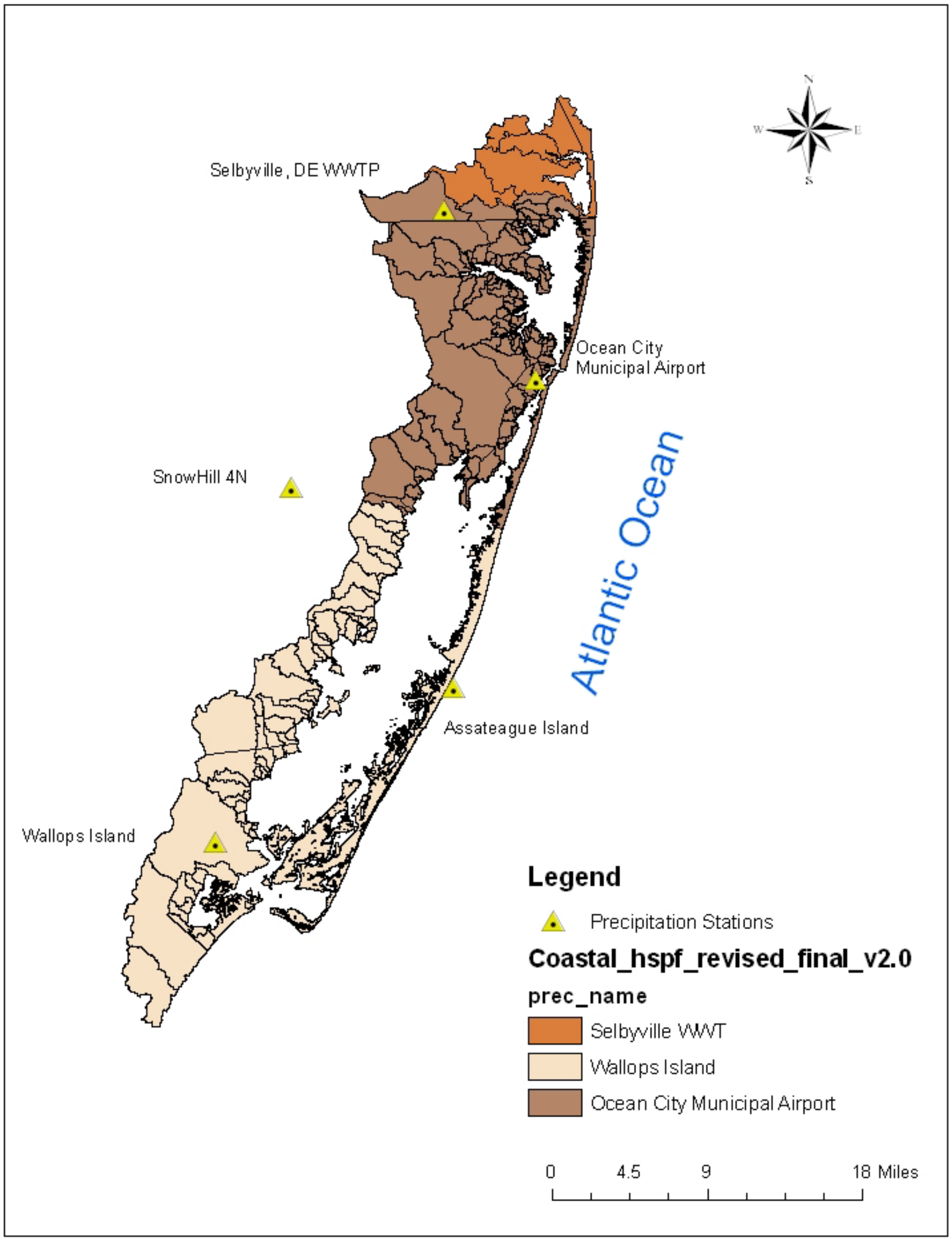

Figure 6. Assignment of precipitation records to model segments and location of precipitation stations in the Coastal Bays and nearby areas.

7.2 Development of F-Tables for Gaged Streams

When channel processes are included in an analysis, use of the HSPF model requires an F-table, which includes data that summarize the relationships between the reach surface area, the stream volume, and the discharge from the reach as a function of the river stage. If they are improperly computed, F-tables can be an inaccurate representation of the stream characteristics because their computations are generally based only on values from one individual site along the reach. Although F-tables were developed for Bassett Creek and Birch Branch and used for model calibration, the routing of flow and water quality was not used by the HSPF, as the segments downstream from these watersheds do not simulate channels. Therefore, use of F-tables will not affect loading discharge to the 3D water quality model.

7.3 Water Quality Database for the HSPF-Model Calibration and Validation

In-stream water-quality data values were obtained from monitoring programs sponsored by MDE, DNR, the National Park Service, and the USGS in the Maryland Coastal Bays area. Data in 1999-2005 used for the watershed model calibration were from DNR and USGS (USGS 2009). The monitored values were used for the calibration of the model in Birch Branch and validation in the Bassett Creek watershed (Tables 22 and 23, respectively). In Birch Branch, observed data were used to compare with simulation results including water temperature (WT), dissolved oxygen (DO), ammonia (NH_4), nitrate (NO_3), organic nitrogen (ORGN), phosphate (PO_4), organic phosphorus (ORGP), and chlorophyll-a (Chl-a) from 1999 to 2005. In Bassett Creek, observation variables are the same as those in Birch Branch, but include no Chl-a measurements. These observed variables were used for the model validation for the Bassett Creek.

Table 21. Data used for the calibration of in-stream water quality at Birch Branch.

DATE	WT	DO	NH4	NO3	ORGN	PO4	TN	ORGP	TP	TSS	Chl-a
	(C°)	mg/l									µg/l
4/21/1999		9.2	0.198	1.95		0.006	2.667		0.043		3.74
6/29/1999		5.4	0.19	0.402		0.015	1.216		0.117		2.99
7/27/1999		4.3	0.228	0.255		0.013	1.052		0.114		2.24
8/23/1999		5.5	0.212	0.269		0.028	0.942		0.127		8.97
9/28/1999		6.5	0.078	5.14		0.013	6.226		0.053		1.92
10/25/1999		9.1	0.146	7.86		0.019	9.124		0.036		0.60
3/22/2000	0.54		1.83	1.3	3.7	0.25		0.28	0.53	62	
4/20/2000	11.8	9.4	0.26	3.9674		0.0286	5.222		0.0956	6.5	4.49
5/10/2000	21.5		0.18	0.96	0.94	2.1	11	0.01	0.09	0.1	
5/15/2000	18.1	6.6	0.391	0.7802	1	0.0165	2.295	0.07	0.1187	15.5	8.22
5/30/2000	13.5		0.26	1.44	0.74	2.5	6	0.03	0.07	0.1	
6/14/2000	19		0.22	0.79	0.76	1.8	10	0.03	0.1	0.13	
6/21/2000	20.3	6.1	0.255	1.1881		0.0174	2.493		0.1164	0.09	1.00
6/28/2000	23		0.16	0.81	0.68	1.7	10	0.04	0.1	0.14	
7/12/2000	20		0.14	1.12	0.72	2	4	0.02	0.07	0.09	
7/20/2000	20.2	6.2	0.198	2.0778		0.237	3.739		0.3964	23.3	3.99
7/27/2000	21.5		0.11	2.19	1.2	3.5	9	0.03	0.08	0.11	
8/9/2000	23.5		0.09	1.77	1	2.9	7	0.03	0.07	0.1	
8/14/2000	20.5		0.26	1.33	1.3	2.9		0.1	0.13	0.23	
8/17/2000	20.4	6.5	0.095	1.8645		0.0138	2.8283		0.0711	0.05	0.50
9/6/2000	18		0.17	1.52	1.1	2.8	10	0.03	0.08	0.11	
9/20/2000	18.5	6.7	0.102	1.0577		0.0101	1.8389		0.0627	3.6	
10/18/2000	16.2	6.4	0.098	1.5733		0.0045	2.199		0.0509	0.04	
2/21/2001	7.8	10.1	0.141	.		0.0086	5.412		0.0456	0.04	5.48
3/13/2001	10.9	8.1	2.304	.		1.09	8.66		2.0791	1.33	37.38
4/24/2001	18.9	7.2	.	.		.	.		.	.	14.20
5/22/2001	15.9	6.1	0.635	.		0.0099	2.636		0.1272	10.2	4.98
6/19/2001	20.5	6.6	0.248	.		0.0236	5.36		0.1093	8.5	2.49
7/25/2001	23.4	5.5	0.176	.		0.0195	1.675		0.1414	0.2	2.99
8/22/2001	21.6	6.3	0.162	.		0.0235	1.935		0.0823	5.2	4.49
9/18/2001	15.7	6.7	0.158	.		0.0093	1.338		0.0727	2.7	9.72

DATE	WT	DO	NH4	NO3	ORGN	PO4	TN	ORGP	TP	TSS	Chl-a
	(C°)	mg/l									µg/l
10/24/2001	18.3	5	0.133	0.214		0.0065	0.767		0.077	4.5	
11/19/2001	9.9	5.2	0.356	0.1041		0.0053	0.7883		0.131	6.5	
12/17/2001	8.7	6.6	0.34	0.2573		0.0069	0.9227		0.0927	3.2	1.50
1/22/2002	4.4	10.2	0.511	2.4752		0.0055	3.363		0.0558	4.1	15.45
2/19/2002	4.9	10.3	0.13	1.7658		0.0068	2.497		0.0446	0.03	4.49
3/19/2002	9.3	9.5	0.227	3.243		0.0184	4.339		0.0928	0.04	7.97
4/29/2002	15.4	7.2	0.256	2.5003		0.0898	4.721		0.2753	23.5	5.98
5/29/2002	20.1	5.9	0.2	0.4596		0.014	1.6		0.1128	0.11	1.50
6/25/2002	21.8	5.5	0.178	0.3346		0.0108	1.137		0.1215	8.5	1.50
7/23/2002	23.7	5.3	0.224	0.2261		0.0276	1.122		0.1338	18.3	
8/20/2002	25.1	5.2	0.428	0.1478		0.0149	1.342		0.1918	0.27	8.97
9/24/2002	19.1	6.6	0.119	0.8302		0.0139	1.807		0.076	0.03	11.21
10/22/2002	12	8.9	0.116	0		0.0084	10.5971		0.031	1.9	0.60
11/19/2002	8.9	9.3	0.13	6.4482		0.05	7.7179		0.1128	0.04	
12/17/2002	4.4	11.2	0.194	6.1906		0.0192	7.2806		0.0414	1.8	
1/30/2003	3.2	11.2	0.482	3.0756		0.0065	3.984		0.0391	1.9	4.79
2/25/2003	4.7	11	0.201	0		0.0221	4.8618		0.062	4.9	2.16
3/17/2003	10.8	9.2	0.361	2.7018		0.0505	4.154		0.1377	8.2	6.36
4/28/2003	14.6	8.6	0.27	1.7619		0.014	2.916		0.0726	0.04	5.98
5/27/2003	14	8.6	0.318	2.6723		0.0453	3.955		0.137	6.8	2.24
6/23/2003	19.2	7.4	0.158	2.889		0.0215	3.9963		0.0982	4.5	1.50
7/29/2003	21.6	6.1	0.13	0.7909		0.021	1.88		0.1487	7.3	2.49
8/25/2003	19.4	6.8	0.116	1.007		0.0272	2.024		0.1427	0.05	2.24
9/23/2003	20.7	6.4	0.187	1.1638		0.0782	3.138		0.3687	41.5	5.23
10/21/2003	14	8.5	0.154	1.9872		0.0146	3.1913		0.0686	3.2	0.75
11/5/2003	17.5	7.2	0.173	2.2514		0.019	3.38		0.0783	4.7	0.50
12/2/2003	6.8	9.9	0.325	2.1665		0.0239	3.2102		0.0642	2.4	1.79
1/20/2004	0.5	12.3	0.375	2.4721		0.0236	.		.	2.1	
2/23/2004	4.8	10.9	0.225	2.2865		0.0112	3.386		0.0526	4.4	18.54
3/23/2004	5.1	11.3	0.23	1.718		0.0079	2.763		0.067	0.09	26.17
4/20/2004	17.9	8	0.334	1.4934		0.0312	2.878		0.1001	0.07	1.50
5/17/2004	19.6	5.2	0.476	1.2694		0.0421	3.076		0.2716	0.26	5.98

DATE	WT	DO	NH4	NO3	ORGN	PO4	TN	ORGP	TP	TSS	Chl-a
	(C°)	mg/l									µg/l
6/28/2004	19.6	5.7	0.146	0.6201		0.0124	1.804		0.1204	10.3	
7/26/2004	20.6	5.3	0.242	0.5962		0.0164	1.62		0.1321	14.3	4.98
8/17/2004	20.1	7	0.181	1.7739		0.114	3.275		0.2111	12.5	3.36
9/13/2004	18.7	6.7	0.152	0.9945		0.0241	1.909		0.1005	6.5	4.49
10/21/2004	14.2	7.6	0.162	1.582		0.0059	2.4161		0.0625	4.7	
11/15/2004	6.9	11	0.17	4.2053		0.0319	5.176		0.0842	6.3	
12/13/2004	8.9	10.1	0.242	4.1714		0.0368	0.1401		0.0915	6.2	0.90
1/27/2005	.	.	.	.		.	.		.	.	1.12
1/27/2005	0.9	13	0.322	.		0.0217	4.406		0.0674	0.06	1.12
2/22/2005	6.5	11.7	0.171	.		0.0534	3.7		0.1819	25.7	4.49
3/21/2005	9.1	6.4	0.227	.		0.0099	2.959		0.0476	4.3	4.11
4/26/2005	12.2	8.6	0.263	.		0.0101	2.074		0.0789	8.5	26.17
5/16/2005	16.7	6.6	0.3	.		0.0108	1.957		0.1206	11.3	9.35
6/21/2005	16.7	6.3	0.2	.		0.0117	1.838		0.1051	6.3	13.46
7/18/2005	24.4	5.9	0.146	.		0.0248	2.245		0.1094	4.3	5.48
8/16/2005	23.8	5.4	0.156	.		0.0193	2.221		0.0997	6.7	3.74
9/20/2005	20.4	5.4	0.167	.		0.0125	1.217		0.102	6.7	0.85
10/11/2005	18	6.4	0.229	.		0.0255	2.813		0.1127	4.3	2.99
11/7/2005	14.5	6.2	0.108	.		0.0057	2.821		0.0525	1.45	
12/5/2005	7.3	9.4	0.188	.		0.0135	6.1026		0.0469	1.95	1.12

WT=water temperature; DO=dissolved Oxygen; NH4=ammonia; NO3=nitrate; OrgN=organic nitrogen; TN=total nitrogen; PO4=phosphate; TP=total phosphorus; OrgP=organic phosphorus; ;TSS=total suspended sediments.

Table 22. Data used for validation of in-stream-water quality at Bassett Creek.

DATE	WT	DO	NH4	NO3	OrgN	TN	PO4	TP	OrgP
	(C°)	mg/l							
1/28/1999	8.1	9.8	0.03	1.11	0.66	1.8	0.01	0.06	0.05
2/8/2000	3.9	10.6	0.03	1.17	0.5	1.7	0.02	0.03	0.01
10/31/2002	10.5	8	0.02	0.53		1.6	0.21	0.4	0.19
12/17/2002	4.7	10.6	0.03	1.08		1.6	0.02	0.04	0.02
1/16/2003	1	10.4	0.05	2.06	0.3	2.4	0.02	0.02	0
1/29/2003	2.2	10.6	0.04	2.46		2.8	0.02	0.02	-0.01
3/3/2003	4.5	9.1	0.03	2.03		2.6	0.01	0.08	0.07
3/5/2003	6.5	8.3	0.06	1.13	1	2.2	0.09	0.27	0.18
3/21/2003	11	7.6	0.02	1.21		1.9	0.02	0.11	0.09
3/31/2003	7.2	8.3	0.05	0.81	1.1	2	0.06	0.18	0.12
4/11/2003	7.2	8	0.04	0.94		2	0.09	0.39	0.3
5/1/2003	14.5	7.8	0.04	1.71		2.3	0.01	0.05	0.04
5/8/2003	14.1	7	0.04	1.39		2	0.02	0.05	0.03
5/22/2003	13.4	4.1	0.75	1.86	1.5	4.1	0.1	0.26	0.16
6/4/2003	15.6	5	0.05	1.41	0.61	2.1	0.02	0.06	0.04
7/3/2003	20.8	5.9	0.13	1.32			0.06	0.19	0.13
7/8/2003	20.8	6.6	0.09	2.23	1	3.4	0.04	0.14	0.1
7/29/2003	20.8	6.3	0.08	0.98	1.3	2.4	0.02	0.15	0.13
8/20/2003	20.3	7	0.07	2.58	1.2	3.9	0.01	0.14	0.13
8/21/2003	20.6	7.2	0.06	3.01	0.95	4	0.18	0.09	-0.09
9/4/2003	22.2	5.8	0.03	0.4		1.6	0.13	0.37	0.24
9/11/2003	17.7	7.6	0.07	2.78	0.61	3.5	0.03	0.08	0.05
10/15/2003	15.5	4.8	0.06	0.82	1.6		0.17	0.44	0.27
10/23/2003	11.1	7.6	0.06	2.41	0.5		0.01	0.04	0.03
10/29/2003	13.4	6.7	0.04	1.24			0.62	0.94	0.32
11/19/2003	14.9	7.3	0.07	1.42	0.53		0.02	0.06	0.04
11/20/2003	12.3	6.8	0.04	0.75			0.17	0.38	0.21
12/11/2003	10.6	7.8	0.07	1.33	1.5		0.25	0.64	0.39
12/23/2003	7.8	9.6	0.03	1.92			0.01	0.03	0.02
1/27/2004	2.2	10.9	0.09	2.28	0.28		0.01	0.03	0.03
2/4/2004	1.6	11.4	0.11	2	0.55		0.03	0.12	0.09

WT=water temperature; DO= dissolved oxygen; NH4=ammonia; NO3=nitrate; OrgN=organic nitrogen; TN=total nitrogen; PO4=phosphate; TP=total phosphorus; OrgP=organic phosphorus.

Figure 7. Segmentation of Coastal Bays HSPF watershed model, locations of U.S. Geological Survey stream-gaging stations, and hourly precipitation stations.

8.0 Model Calibration

The calibration process involved adjustment of the key model parameters used to represent the hydrologic processes, nutrient uptake, and transport processes until acceptable agreement between simulated flows, and water quality parameters including nutrients and algae and field measurements were achieved. Birch Branch was selected as the calibration site as both USGS gage data and in-stream observations of water quality parameters are available.

Because the watershed model is driven by hourly precipitation and evapotranspiration, the accuracy of the model simulation highly depends on the accuracy of these forcing data. One key model input data is evapotranspiration. This data is not readily available based on measurements. The integrated effects of radiation, wind, temperature, and humidity on the evaporation affecting crop transpiration can be simulated using a pan coefficient. This coefficient is obtained from pan evaporation measurements that, in practical terms, involves a pan being filled with water and the decrease in water depth is then measured after a given period (e.g. mm/day); then the E-pan value is multiplied by a pan coefficient Kpan, to obtain the ETo (MDE and UMCP 2010).

ETo = Kpan Epan
Where:

> ETo reference crop evapotranspiration [mm/day],
> Kpan pan coefficient [-], and
> Epan pan evaporation [mm/day].

An adjustment of evapotranspiration was conducted based on the initial model calibration of hydrological processes (MDE and UMCP, 2010). After several attempts for calibration, it was decided that a pan coefficient was needed for the Birch Branch analyses. Without the pan coefficient adjustment, the calibrated parameters did not accurately predict the actual discharges. The most telling difference was in the evapotranspiration (ET) values and the water balances. The actual ET was 0.0859 in/day versus a predicted rate of 0.0620 in/day, an overprediction of 27.8%. The water balance showed an actual daily rate of 0.0232 in/day. The predicted values were overestimated by 0.0031 in/day. The disparity in the actual water balance is due to the very significant error in ET. The disparity in the total surface runoffs, actual vs. predicted, is much less (0.0502 in/day vs. a predicted rate of 0.0527 in/day), which is a difference of 4.9% (under prediction). This shows that the calibration emphasized fitting the daily discharges, with little emphasis on the ET or water balance. The pan coefficient of 0.75 was then applied to the ET data in the Birch Branch (MDE and UMCP 2010).

8.1 Calibration of Daily Discharge

Birch Branch: Daily Discharge and Water Balance

Figures 8-10 show a comparison of model results against observation time series and accumulative flow distribution, which show that model simulated flow agreed well with observed flow at the Birch Branch Station. The correlation coefficient between modeled results and observations reached 0.72. The root-mean-square error is 14.5 cfs/s.

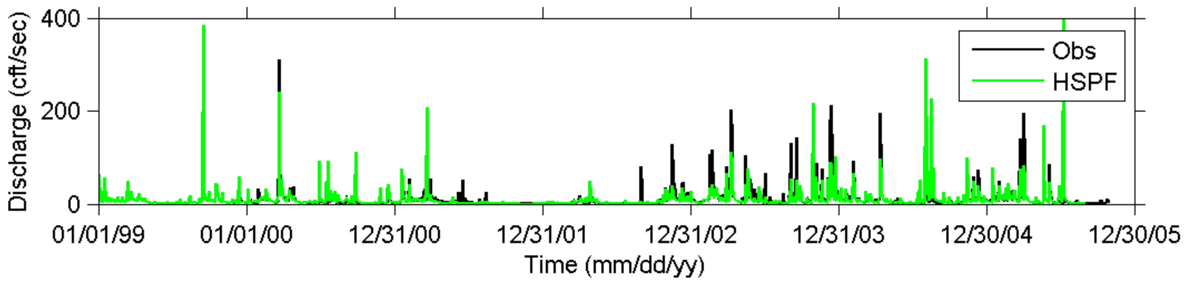

Figure 8. Observed and predicted daily discharge for Birch Branch watershed

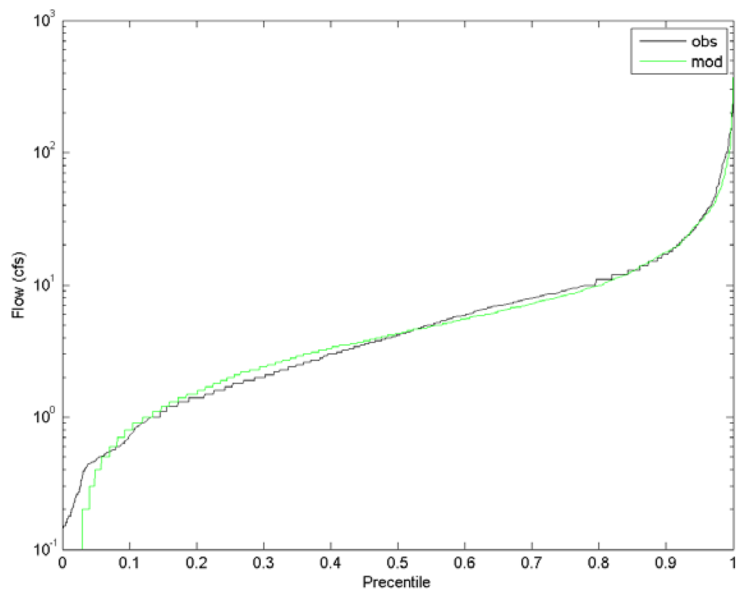

Figure 9. Observed and predicted daily discharge percentile distributions for Birch Branch watershed

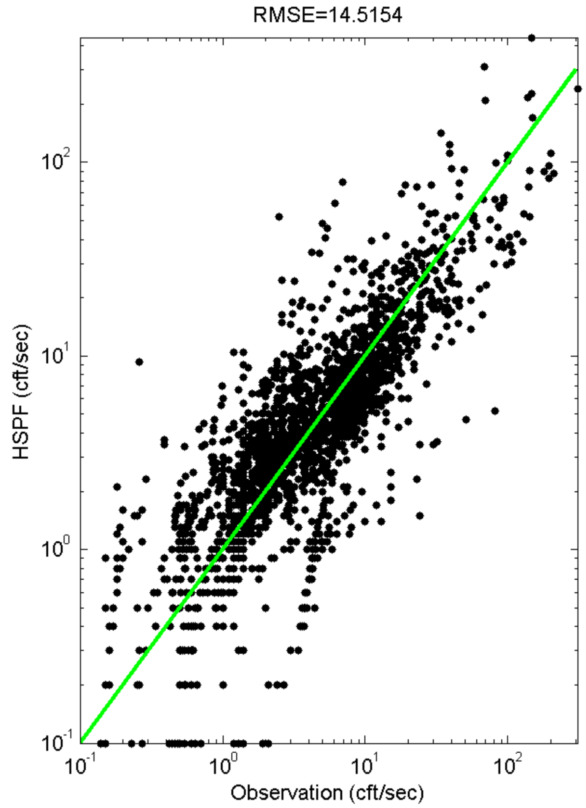

Figure 10. Observed and predicted daily discharge fit diagram for the Birch Branch watershed. The root-mean-square error (rmse) is about 14.5. The green line indicates a perfect match.

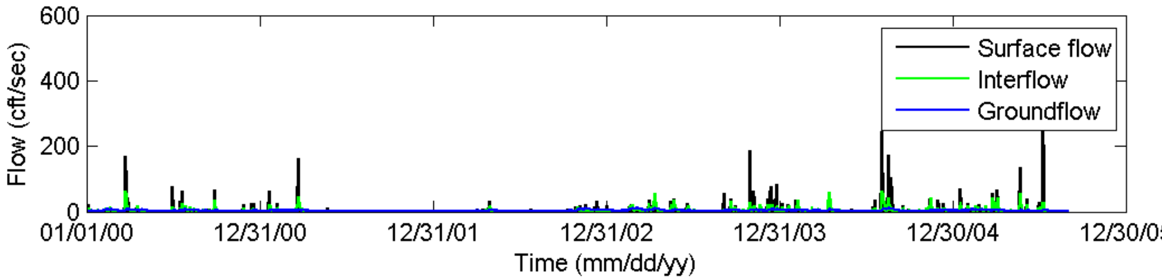

Figure 11. Flow distribution for Birch Branch watershed.

Figure 11 shows the distribution of surface flow (27.7%), interflow (20.5%), and groundwater (51.8%) in the Birch Branch watershed.

Birch Branch: Peak Discharge Rates

To assess the accuracy of the fitted model for Birch Branch, the ten largest peak discharges per year were analyzed. Table 23 includes the goodness-of-fit statistics for the ten largest peak discharges in each of the six years of record. In four of the six years, the average of the predicted flows was less than the average of the measured flows. However, over the six-year period, the actual peaks were overpredicted by about 1%, or about 0.68 cubic feet per second (cfs). Such a bias should not significantly affect the accuracy of long-term water quality estimates.

Table 23. Summary of 10 peak discharges for Birch Branch applying the pan coefficient adjustment

year	n	Mean peak discharge (cfs)		Maximum peak discharge (cfs)		Bias (cfs)	Relative bias	Se (cfs)
		Actual	Predicted	Actual	Predicted			
2000	10	64.80	77.69	311.00	237.74	12.89	0.20	38.19
2001	10	40.90	43.50	69.00	212.09	2.60	0.06	49.07
2002	10	46.70	29.58	128.00	51.15	-17.12	-0.37	28.32
2003	10	143.00	96.80	211.00	220.17	-46.20	-0.32	52.13
2004	10	87.90	112.27	195.00	316.18	24.37	0.28	47.00
2005	10	89.90	109.27	195.00	445.62	19.37	0.22	83.70
mean	10	78.87	78.19	184.83	247.16	-0.68	0.01	49.73

In addition to the bias, the standard deviation of the errors (Se) was computed using the ten largest events in each of the six years. The values ranged from 28.32 cubic feet per second (cfs) to 83.0 cfs. The standard error measures the variation of the predicted values relative to the true values, with a small standard error suggesting a good fit. The average of the standard errors is 49 cfs, which is approximately half of the mean annual peaks. This is generally considered acceptable. If the 30 largest peak discharges are analyzed (see Table 24), both the biases and standard errors will decrease because the additional twenty events in any year are closer to the mean. The average of the biases for the six years was 0.26 cfs (a slight overprediction), which was about 5.0% of the average measured peak. This is slightly less biased than for the ten largest peaks. The standard error decreased to about 29.0 cfs, which is approximately two-thirds of the standard error for the ten largest peaks.

Table 24. Summary of 30 peak discharges for Birch Branch

year	n	Mean peak discharge (cfs)		Maximum peak discharge (cfs)		Bias (cfs)	Relative bias	Se (cfs)
		Actual	Predicted	Actual	Predicted			
2000	30	28.49	38.25	311.00	237.74	9.76	0.34	23.16
2001	30	18.54	18.23	69.00	212.09	-0.31	-0.02	28.42
2002	30	19.95	15.95	128.00	51.15	-4.00	-0.20	16.54
2003	30	79.00	52.81	211.00	220.17	-26.19	-0.33	34.15
2004	30	37.55	49.95	195.00	316.18	12.40	0.33	27.98
2005	30	37.64	44.40	195.00	445.62	6.75	0.18	48.35
mean	30	36.86	36.60	184.83	247.16	-0.26	0.05	29.77

Birch Branch: Low Flow Discharge Rates

For the optimum set of parameters for Birch Branch, the mean of the twenty lowest discharges over the six years was 1.60 cfs (see Table 25), while the mean of the predicted low flows was 1.68 cfs. Thus, the average of the six biases was about 0.10 cfs (overprediction), which is about 5% of the mean of the low flow averages. The standard error was 0.44 cfs, which is about 27% of the mean value.

Table 25. Summary of 20 low flows for Birch Branch

year	n	Mean low discharge (cfs)		Maximum low discharge (cfs)		Bias (cfs)	Relative bias	Se (cfs)
		Actual	Predicted	Actual	Predicted			
2000	20	1.81	2.14	2.80	3.11	0.33	0.18	0.49
2001	20	0.46	0.62	0.57	1.44	0.16	0.35	0.42
2002	20	0.77	0.93	2.00	2.00	0.16	0.21	0.25
2003	20	2.91	2.29	5.20	3.73	-0.61	-0.21	0.71
2004	20	1.73	1.64	3.00	2.68	-0.09	-0.05	0.24
2005	20	1.93	2.45	3.80	4.60	0.52	0.27	0.54
mean	20	1.60	1.68	2.90	2.93	0.08	0.13	0.44

For the analyses of the 50 lowest flows in each year, the mean bias was approximately 0.8 cfs (Table 26), which is similar with the bias of the twenty lowest flows. However, since the 20 lowest flows have a smaller mean than that of the smallest 50, the bias is much smaller from a relative standpoint. The mean standard error of about 0.43 also is similar with that for the twenty lowest flows. Overall, the calibrated model provides a good fit for the low flows.

Table 26. Summary of 50 low flows for Birch Branch

year	n	Mean low discharge (cfs)		Minimum low discharge (cfs)		Bias (cfs)	Relative bias	Se (cfs)
		Actual	Predicted	Actual	Predicted			
2000	50	4.86	3.04	18.00	5.43	-1.81	-0.37	3.97
2001	50	2.19	2.43	6.60	9.03	0.24	0.11	0.72
2002	50	3.70	2.61	21.00	6.24	-1.09	-0.30	3.18
2003	50	9.12	6.91	45.00	33.79	-2.21	-0.24	3.62
2004	50	5.13	3.55	34.00	13.43	-1.59	-0.31	3.70
2005	50	4.09	5.37	9.30	16.94	1.28	0.31	1.96
mean	50	4.85	3.99	22.32	14.14	-0.86	-0.13	2.86

Bassett Creek: Verification of Daily Discharge and Water Balance

As a measure of verification, the parameters and precipitation data from the calibrated model for Birch Branch were applied to Bassett Creek. The objective of this verification was to determine if the calibrated parameters from Birch Branch could provide reasonable predictions of runoff when transferred to ungaged watersheds. Figures 12-14 show the comparison between simulated runoffs at the Bassett Creek Station. It can be seen the predicted runoffs agreed with observations very well. The correlation coefficient reached approximately 0.86.

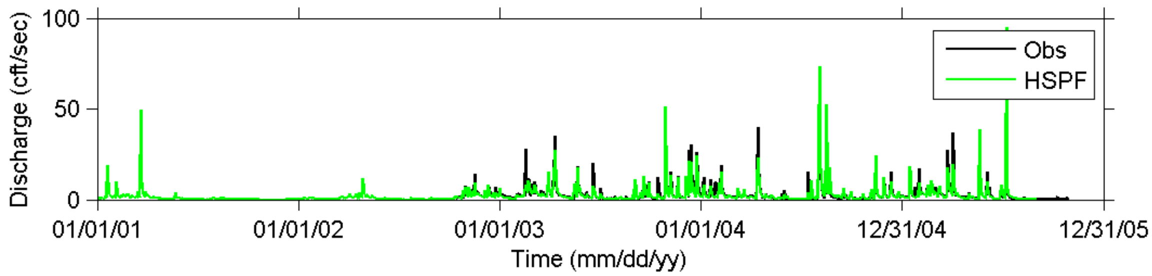

Figure 12. Observed and predicted daily discharge for Bassett Creek watershed

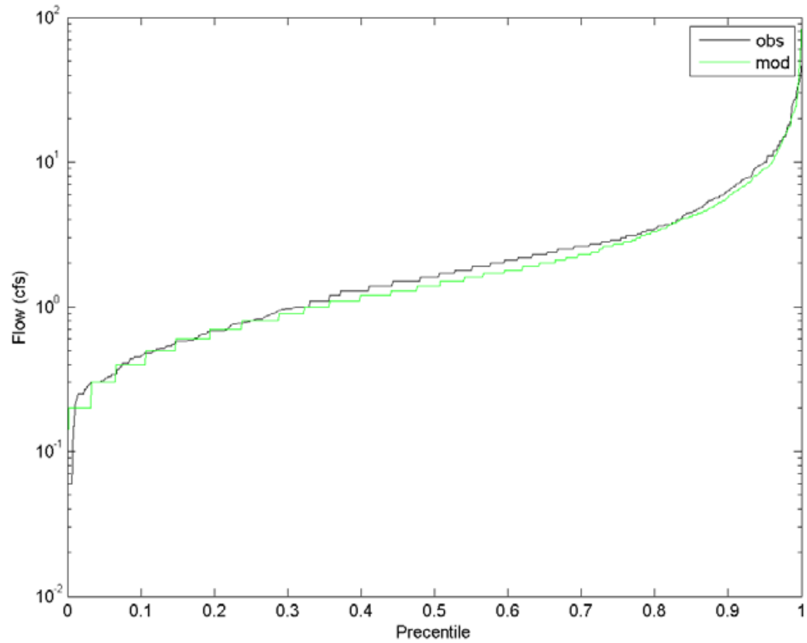

Figure 13. Observed and predicted daily discharge percentile distributions for Bassett Creek watershed

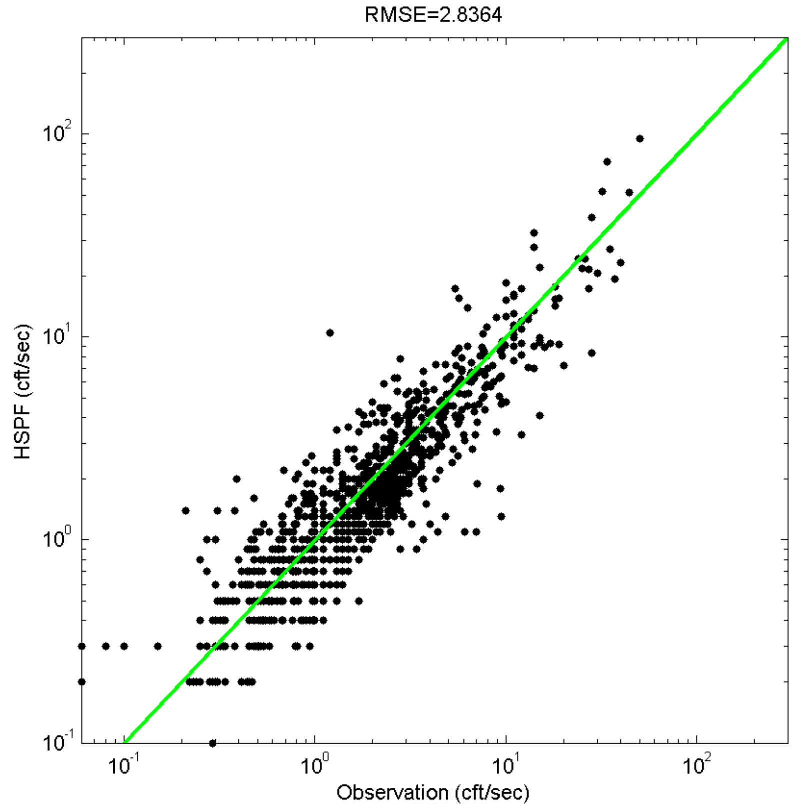

Figure 14. Observed and predicted daily discharge fit diagram for Bassett Creek watershed. The root-mean-square error (rmse) is about 2.8. The green line indicates a perfect match.

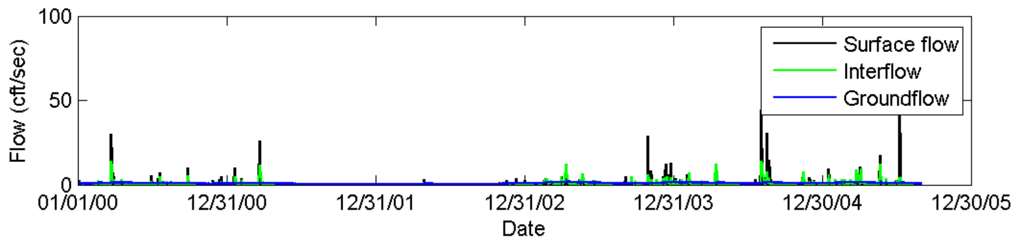

Figure 15. Flow distribution for Bassett Creek watershed

Figure 15 show the distribution of surface flow (18%), interflow (32%), and groundwater (50%) in the Bassett Creek.

Bassett Creek: Verification of High and Low Flows

The peak discharges were underpredicted by 7%, with average predicted and actual flows of 10.05 and 11.14 cfs, respectively (see Table 27). The standard error for the three full years of record was approximately 6.02 cfs. These were less than the means of the actual flows but on average were 54% to 68% of the actual flows. These are slightly larger than the calibrated values, but not sufficiently large to suggest that the calibrated model is inaccurate.

Table 27. Summary of peak discharges for Bassett Creek using Birch Branch precipitation and calibrated parameters.

year	n	Mean peak discharge (cfs)		Maximum peak discharge (cfs)		Bias (cfs)	Relative bias	Se (cfs)
		Actual	Predicted	Actual	Predicted			
2003	30	14.00	10.60	44.00	35.70	-3.39	-0.24	6.87
2004	30	10.25	10.53	40.00	58.77	0.28	0.02	5.78
2005	30	9.17	9.02	50.00	67.37	-0.14	-0.01	5.41
mean	30	11.14	10.05	44.67	53.95	-1.08	-0.07	6.02

The low flows were underpredicted by 2% (see Table 28), with weighted mean actual flows of 1.46 cfs and a mean predicted low flow of 1.32 cfs. The average standard error was 1.30 cfs, which is 89% of the mean actual flow. Overall, the low flows predicted from the transfer of precipitation and calibrated parameters are in good agreement with the actual values.

Table 28. Summary of low flows for Bassett Creek using Birch Branch precipitation and calibrated parameters.

year	n	Mean low discharge (cfs)		Maximum low discharge (cfs)		Bias (cfs)	Relative bias	Se (cfs)
		Actual	Predicted	Actual	Predicted			
2003	50	1.87	1.56	9.30	6.07	-0.31	-0.17	0.74
2004	50	1.65	0.99	14.00	1.33	-0.66	-0.40	2.55
2005	50	0.87	1.40	2.30	3.70	0.53	0.61	0.62
mean	50	1.46	1.32	8.53	3.70	-0.14	0.02	1.30

Summary of Calibration Results

While some of the biases and standard error may seem large, it is important to keep in perspective that some factors can contribute to these discrepancies. First, the rainfall data used in calibration were not on-site or complete. The spatial separation between the rain gage location and the watershed can introduce significant errors because the rainfall recorded at the gage were not the exact rainfall on the watershed. Second, the convergence criteria (mainly because of the lack of measured data) may not include all the elements occurring in the real process. Third, intercorrelation between the model components and parameters confounds the calibration process because different sets of parameter values can provide the same level of accuracy. This interdependence cannot be avoided, and is inherent to any watershed modeling exercise. Despite these common problems in model calibration, the results presented herein are suitable for a model intended for regulatory purposes.

8.2 Water Quality Calibration

The calibration of the water quality for Bassett Creek and Birch Branch was also performed based on instream observations. For Birch Branch, measured data for the model calibration were available from 1999 to 2005, including NH_4, NO_3, and PO_4. In contrast, for Bassett Creek, measured data for model calibration were only available from 2002 through 2004 and included very limited measurements.

Calibration criteria were tested, including the calibration of the predicted edge-of-stream (EOS) loads to the reported values in the area by CBP-P5 (Table 29). The CBP-P5 EOS loading and unit loading of each landuse were used as a guideline. The final calibration was conducted by using the parameters obtained from the calibration of the hydrology and independently calibrating the parameters controlling the inland and the in-stream water quality processes. Because nutrient loading inputs to the watershed, including application of fertilizer, manure, atmospheric deposition, and septics, were compiled based on the best available information, a few model parameters that need to be adjusted are nutrient uptake, initial nutrient available in the soil, and runoff parameters associated with urban land use. Initial parameter values that represent water quality processes were developed from the HSPF model conducted by the USGS for the Delaware Inland Bays watershed (Gutiérrez-Magness and Raffensperger, 2003), and values used by the CBP-P5. A few parameters related to sediment sorption and storage were also adjusted during the model calibration processes. The criterion for the calibration was the match of the hourly predicted in-stream concentrations to the measured in-stream concentrations. The main objective of the calibration was the attainment of the measured in-stream concentrations, while the unit loadings of each land use category are within the same order of unit loadings of the CBP-P5. As a measure of verification, the parameters obtained from the model calibration of Birch Branch were applied to Bassett Creek. The objective of this verification was to determine if the calibrated parameters from Birch Branch could be used to the entire watershed to provide reasonable predictions of runoff loads. Model calibration results for Birch Branch are presented in Figures 16-18. The verification results for Bassett Creek are shown in Figures 19-21. It can be seen that model results are satisfactory overall.

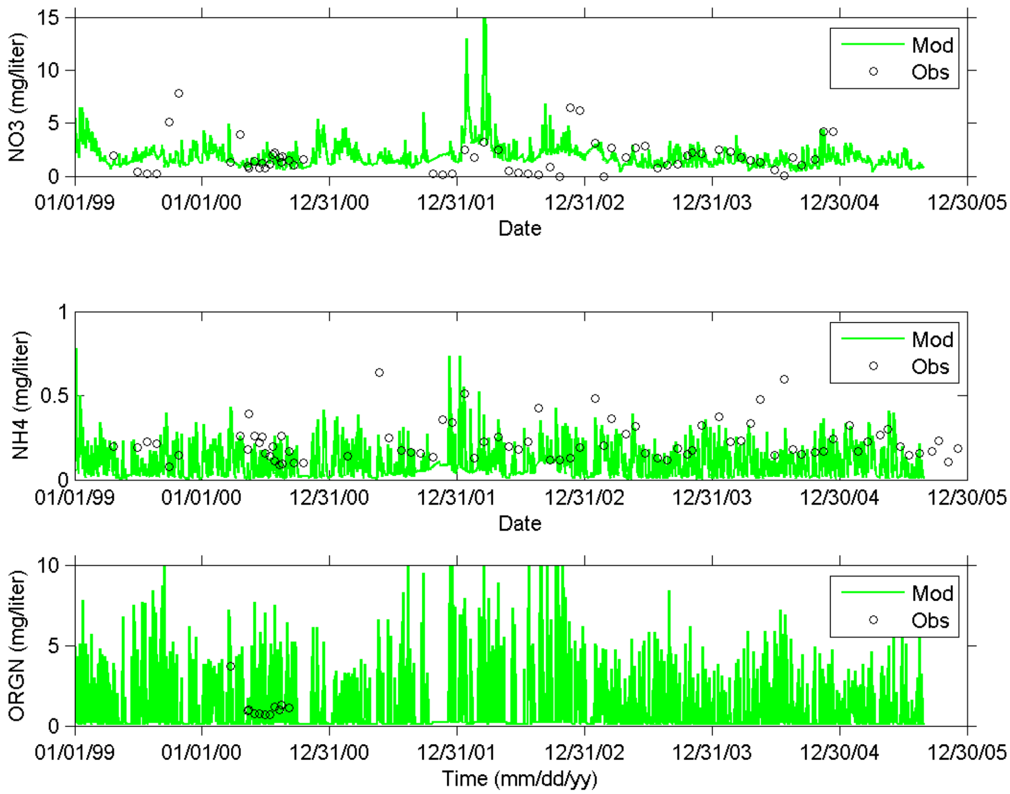

Figure 16A. Simulated daily concentrations of nitrate, ammonia, and organic nitrogen, and observed instantaneous values for Birch Branch during the calibration period.

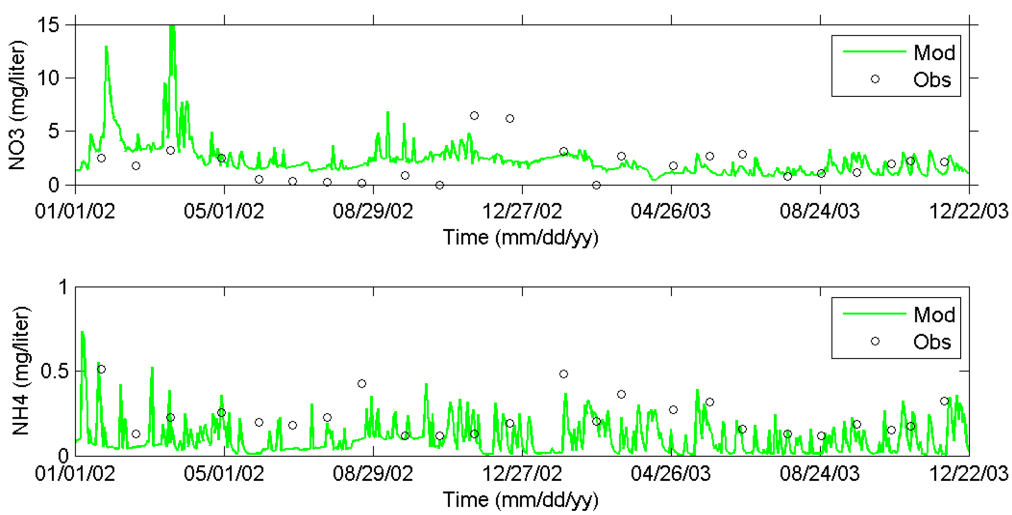

Figure 16B. Simulated daily concentrations of nitrate, ammonia, and observed instantaneous values for Birch Branch during 2002-2003.

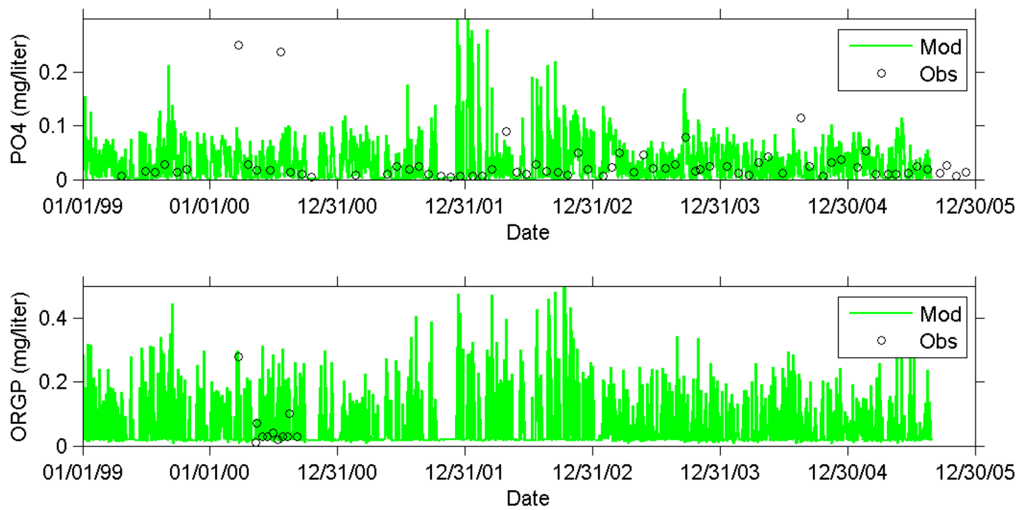

Figure 17A. Simulated daily concentrations of phosphate and organic phosphorus, and observed instantaneous values for Birch Branch during the calibration period.

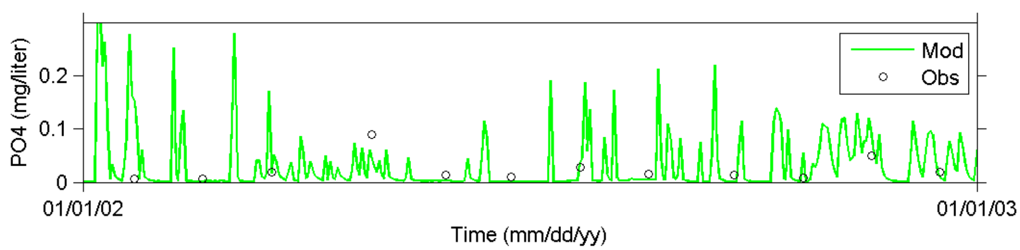

Figure 17B. Simulated daily concentrations of phosphate and observed instantaneous values for Birch Branch during 2002-2003.

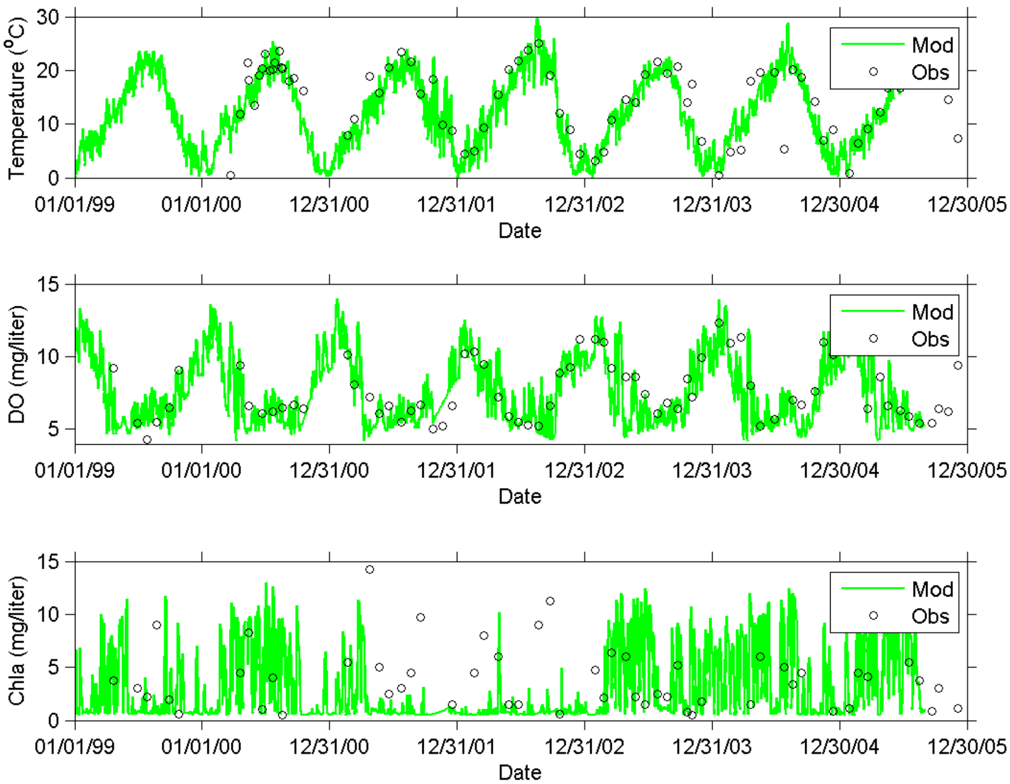

Figure 18. Simulated daily water temperature, dissolved oxygen concentrations, and chlorophyll *a*, and observed instantaneous values for Birch Branch during the calibration period.

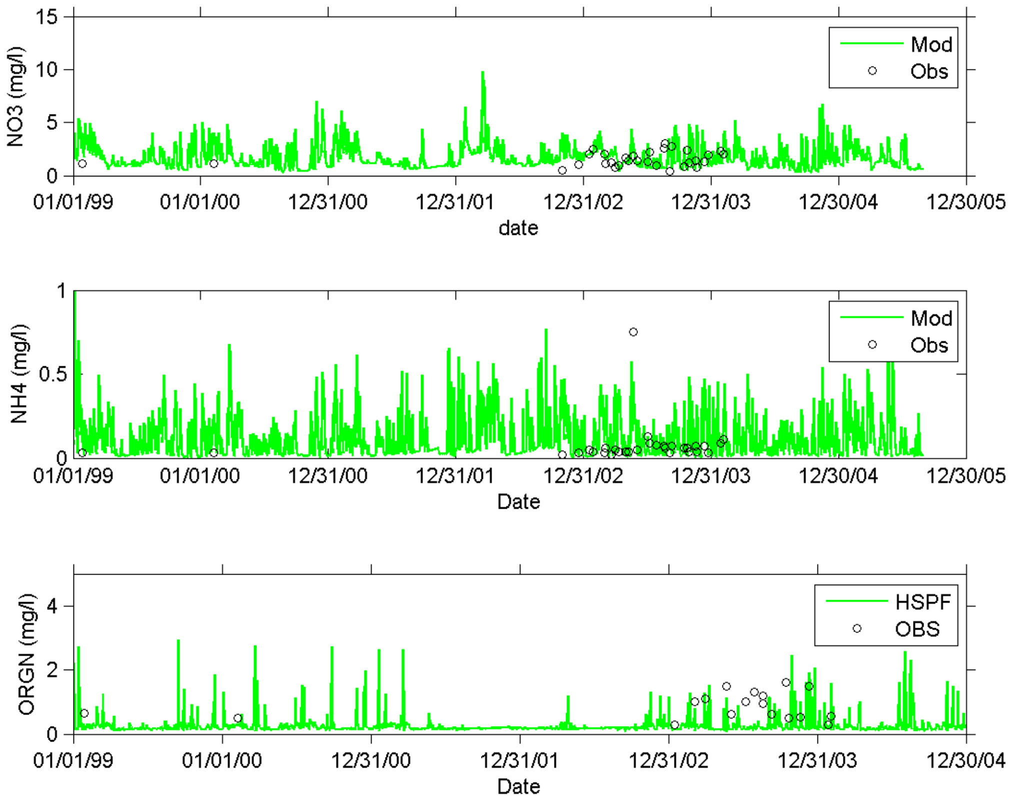

Figure 19A. Simulated daily concentrations of nitrate, ammonia, and organic nitrogen, and observed instantaneous values for Bassett Creek during the calibration period.

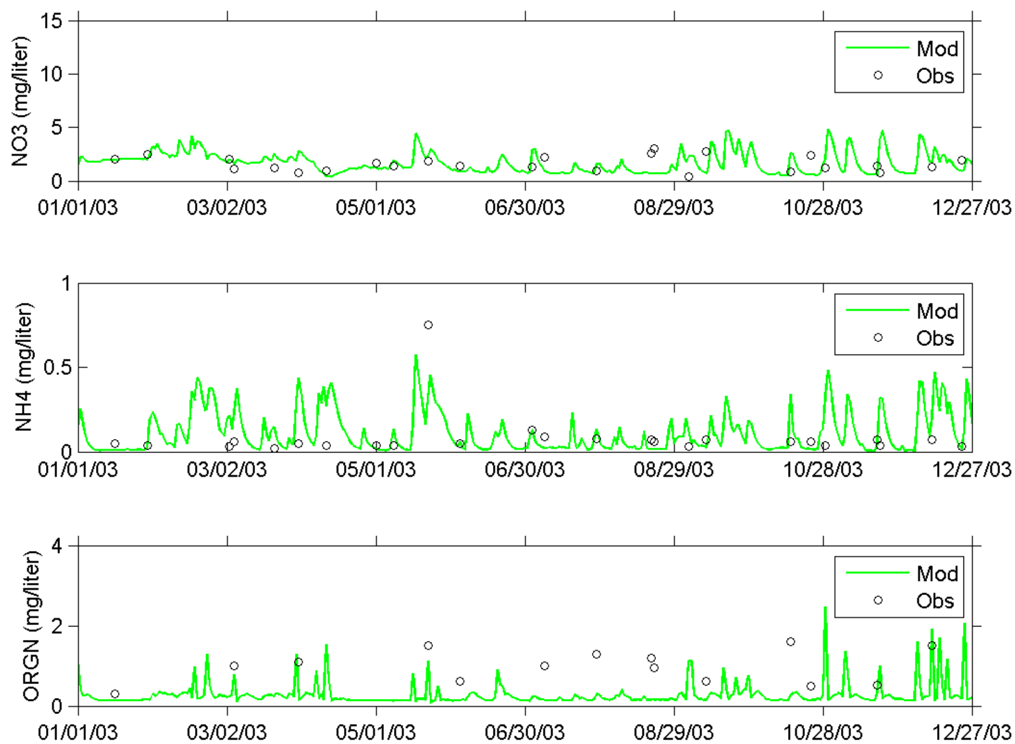

Figure 19B. Simulated daily concentrations of nitrate, ammonia, and organic nitrogen, and observed instantaneous values for Bassett Creek during 2003

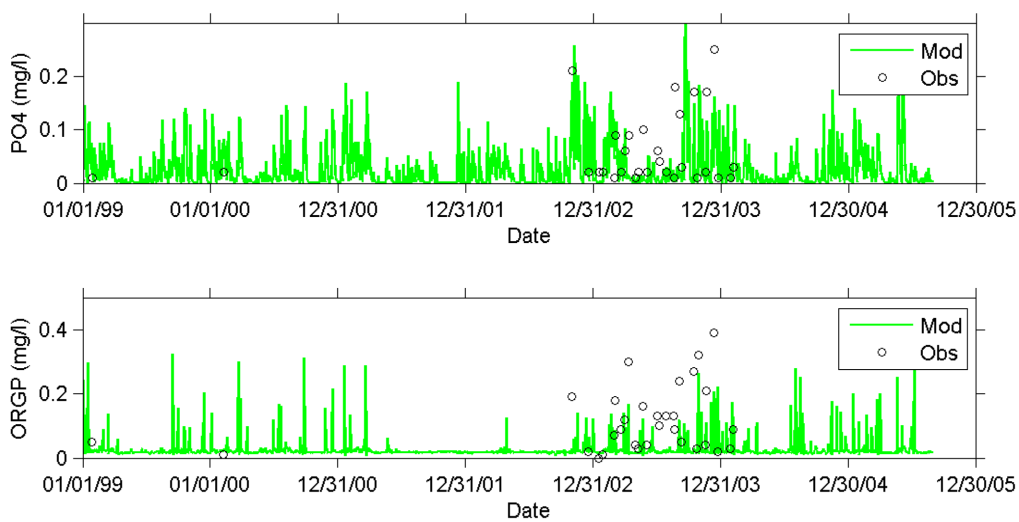

Figure 20A. Simulated daily concentrations of organic phosphorus and phosphate and observed instantaneous values for Bassett Creek.

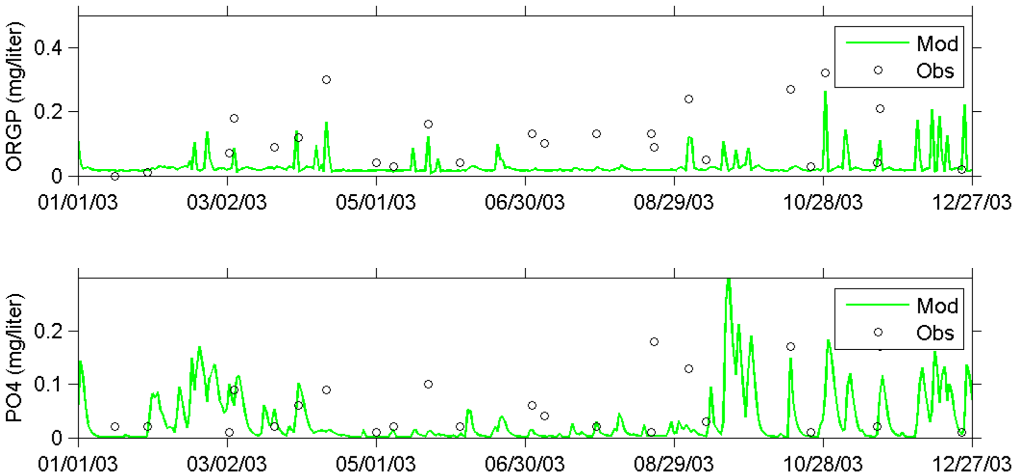

Figure 20B. Simulated daily concentrations of phosphate and organic phosphorus and observed instantaneous values for Bassett Creek during 2003.

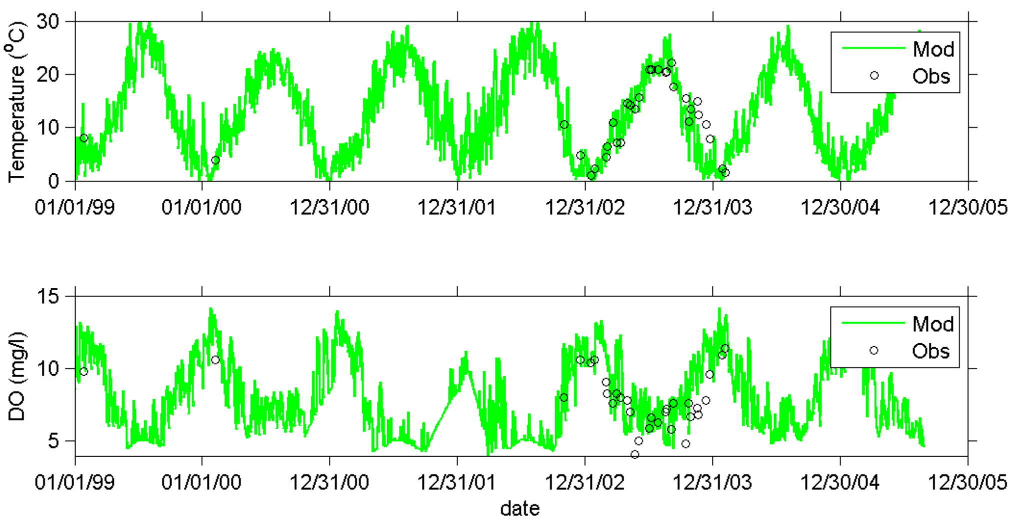

Figure 21. Simulated daily water temperature and concentrations of dissolved oxygen, and observed instantaneous values for Bassett Creek.

Edge-of-Stream Loads Calibration for Birch Branch and Bassett Creek

The corresponding unit nutrient loadings of each land use for the calibration and verification watersheds of Bassett Creek and Birch Branch are listed in Table 29. As in the hydrological simulation, data for the year 1998 were used as the initialization period so the predictions for this year were not used to assess model performance. The initiation period allows the model to reach equilibrium. It can be seen that the model output using current loading input data are on the same order as CBP-P5.3. However, it differs to CBP-P5.3 for some land use. The differences are a result of seasonality and the high resolution of watershed segmentation, incorporating manure and fertilizer application, septic contribution, and crop nutrient uptake which differs from watershed to watershed.

Total nitrogen and phosphorus distributions over a seven-year period are shown in Table 30 for Birch Branch and Bassett Creek.

Table 29. Average of predicted 2002 EOS loads of CBP-P5.3 for the Eastern Shore and for the period 2000-2005 calibrated edge-of-stream loads in Bassett Creek and Birch Branch for the Maryland Coastal Bays watershed model.

TN lb/ac/yr	FOR	NHI	NHO	NHY	NLO	HYW	PAS	BAR	PERV	IMP
Birch Branch	0.69	13.42	14.49	10.10	12.59	11.53	7.47	10.89	12.76	8.71
Bassett Creek	0.69	13.10	14.49	10.64	11.88	11.53	7.47	10.89	12.76	8.71
CBP-P5.3 (Eastern Shore)	1.77	15.60	24.12	2.93	14.05	5.64	10.46	15.98	7.93	7.85
TP lb/ac/yr	**FOR**	**NHI**	**NHO**	**NHY**	**NLO**	**HYW**	**PAS**	**BAR**	**PERV**	**IMP**
Birch Branch	0.05	1.12	1.00	0.80	0.70	0.88	0.40	1.06	1.43	0.54
Bassett Creek	0.05	1.12	1.00	0.80	0.70	0.88	0.40	1.06	1.43	0.54
CBP-P5.3 (Eastern Shore)	0.12	1.56	2.41	0.12	1.26	0.06	0.73	7.92	0.76	2.32
Sediment (Tons/acre/yr)	**FOR**	**NHI**	**NHO**	**NHY**	**NLO**	**HYW**	**PAS**	**BAR**	**PERV**	**IMP**
Birch Branch	0.07	0.88	0.88	0.37	0.29	0.55	0.19	1.39	1.21	7.07
Bassett Creek	0.07	0.88	0.88	0.37	0.29	0.55	0.19	1.39	1.21	7.07
CBP-P5.3 (Eastern Shore)	0.007	0.152	0.125	0.057	0.086	0.137	0.028	2.034	0.041	0.271

Table 30. Predicted annual loads per year (TN and TP in lbs; SED in tons) for Birch Branch and Bassett Creek watersheds. The load for 2005 is only from Jan through August. Precipitation associated with these stations are in parentheses with units of inches.

		1999 (45.60)	2000 (49.05)	2001 (40.17)	2002 (23.65)	2003 53.50)	2004 (54.08)	2005 (41.36)
Birch Branch	TN	24,393	30,882	18,379	11,236	42,123	45,347	38,250
	TP	1,799	1,931	1,087	691	3,053	3,512	2,752
	SED	1,865	1,734	861	712	2,350	3,354	2,941
Bassett Creek	TN	7,118	9,702	5,737	2,425	13,240	14,619	11,773
	TP	498	566	326	124	922	1,057	831
	SED	406	416	216	116	579	849	688

8.3 Edge-of-Stream Loads

For the ungaged watersheds, the calibrated model parameters used for Birch Branch and Bassett Creek were applied to these watersheds. The watershed specific nutrient sources inputs including manure, fertilizer application, failing of septic systems, and atmospheric deposition associated with each watershed. Estimated inputs for these sources were applied to each sub-watershed based on land uses type. Therefore, the variation of nutrients for different subwatersheds can be simulated. The simulated total load edge-of-stream loads are summarized for the, Maryland watershed, and Delaware and Virginia watersheds, respectively, from 1999-2005. These results are summarized in Table 32. For management purposes, loadings for each waterbody are summarized in Table 33. Total loadings of nitrogen and phosphorus are plotted in Figures 22-23. It can be seen that nutrients are proportional to precipitation and runoff in general. The lowest nutrient runoff occurred in the year 2002, a dry year, while high nutrient runoff occurred during the wet year period from years 2003-2004.

Table 31. Predicted nutrient (lbs) and sediment loads (tons) for the Coastal Bays watershed and the Maryland portion of the watershed.

		1999	2000	2001	2002	2003	2004	2005
MD-VA-DE	TN	928,180	1,197,762	844,738	520,571	1,549,662	1,680,086	1,406,609
	TP	71,904	80,129	51,511	29,618	121,621	147,999	117,545
	SED	107,845	102,808	53,539	47,271	130,592	176,075	152,310
Maryland	TN	660,410	452,847	291,619	860,181	941,729	780,969	660,410
	TP	43,105	27,333	16,259	68,541	83,805	66,405	43,105
	SED	78,433	72,922	36,974	35,539	93,755	124,120	107,738

* The load estimated for 2005 is only from January through August

Table 32. Predicted nutrient (lbs) and sediment loads (tons) for the Coastal Bays (each Bay watershed in the Coastal Bays).

		1999	2000	2001	2002	2003	2004	2005
Assawoman	TN	222,857	265,675	165,000	123,513	356,218	382,076	309,802
Wight		257,267	305,314	192,341	149,140	408,905	436,454	351,603
Newport		120,198	147,554	93,128	60,761	199,635	221,706	184,565
Sinepuxent		26,682	28,574	19,879	19,291	37,903	41,285	34,562
Chincoteague		301,176	450,645	374,389	167,866	547,000	598,565	526,077
Assawoman	TP	17,892	18,255	10,244	7,567	29,179	36,386	28,310
Wight		20,185	20,177	11,457	8,961	33,439	40,446	31,567
Newport		9,288	9,460	5,361	3,365	16,155	19,972	15,898
Sinepuxent		2,279	2,049	1,153	1,103	3,714	4,933	3,928
Chincoteague		22,260	30,187	23,296	8,622	39,133	46,262	37,842
Assawoman	TS	28,844	26,108	12,664	12,897	34,979	45,341	37,976
Wight		37,859	33,691	16,145	17,923	44,593	56,558	48,082
Newport		14,970	13,306	6,452	6,412	18,024	24,476	21,385
Sinepuxent		5,998	5,126	2,414	2,947	6,811	8,582	7,503
Chincoteague		20,174	24,576	15,863	7,091	26,185	41,119	37,364

*load estimated for 2005 is only from January through August.

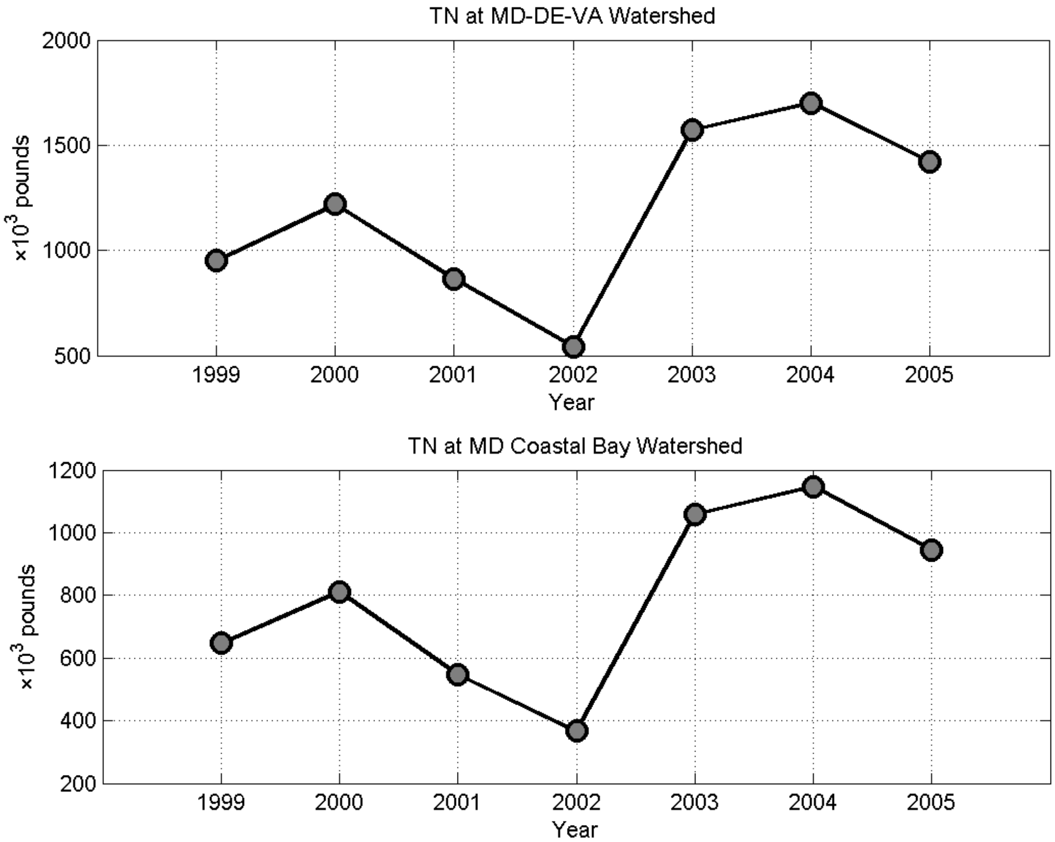

Figure 22. Predicted annual loads of total nitrogen for the MD-DE-VA Coastal Bays Watershed, and in Maryland's portion of the Coastal Bays watershed.

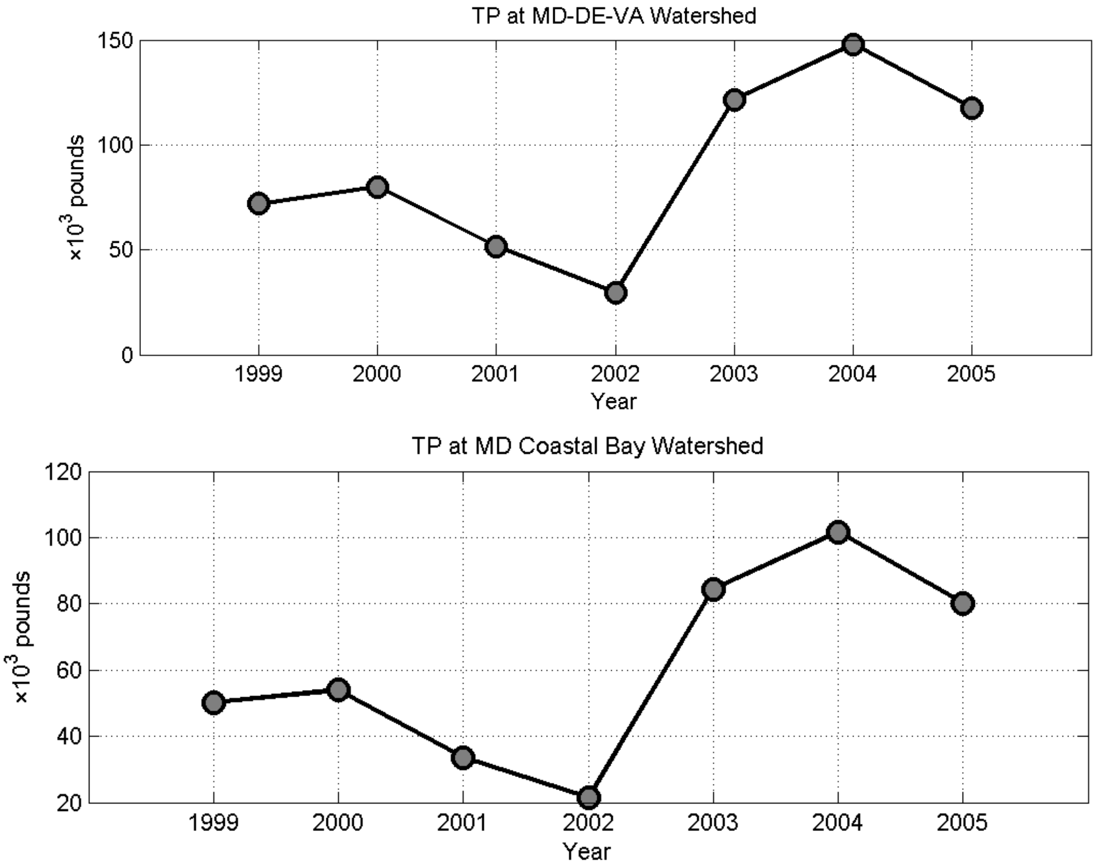

Figure 23. Predicted annual loads of total phosphorus in the MD-DE-VA Coastal Bays watershed and in Maryland's portion of the Coastal Bays watershed.

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Appendix A

Report on the reclassification of land use for the Maryland Coastal Bays Watershed model, using Worcester County database

Date: February 19, 2009

To: the Maryland Department of the Environment
Attention: Melissa Chatham
From: Angelica Gutierrez-Magness
University of Maryland-ENCE Department

Reference: Coastal Bays Watershed Model

The purpose of this report is to document the development of the land use database for the Maryland Coastal Bays Watershed model using the Worcester County database. A reclassification of the database "Lndcvr04_DRAFT_1_29_09.gdb" provided on January 29, 2009 by Worcester County was completed using the following methodology. The purpose of the reclassification was to group categories that could be simulated in the model with similar hydrological characteristics, and that the amounts and types of nutrients applied to the reclassified categories were also similar.

1. The file Lndcvr04_DRAFT_1_29_09.gdb was converted into a shapefile using ARCMAP 9.2 and given the same name to the converted file but with the extension .shp.
2. To contain the reclassification of land use for the HSPF model, a field called "HSPF_ID" was added to the attribute table of the shapefile Lndcvr04_DRAFT_1_29_09.shp. The HSPF land use categories are shown in Table A1.

Table A1. HSPF land use categories.

HSPF_ID	Description
1	High Intensity Developed Impervious (HIDI)
2	Low Intensity Developed Impervious (LIDI)
3	Agriculture (Ag)
4	Water
5	Forest
6	Bare
7	Pasture
8	High Intensity Developed Pervious (HIDP)
9	Low Intensity Developed Pervious (LIDP)
10	Chicken Houses

Notes:

a) The “Agriculture” category is later on divided among specific crops using the proportions of crops in the database of the Chesapeake Bay Program Watershed Model for Worcester County;
b) The category number 4 (water) is not simulated in the HSPF model;
c) The areas in the category number 10 (chicken houses) is later on added to the “Low intensity Developed Impervious” areas. The assignment of a value for this category is to cross-reference with ancillary data, for the location of poultry houses. The location of these building provides an additional tool for a more accurate calculation of manure by model segment.

3. The shapefile Lndcvr04_DRAFT_1_29_09.shp was intersected with the watershed model segmentation contained in the shape file “Coastal_hspf.shp”. the intersected file was named “Coastal_hspf_Intersect.shp”. All the attributes from both sources were kept in the intersection.
4. Using the dissolved process from GIS and the shape file Coastal_hspf_Intersect.shp, three attributes were selected: 1) Classification and Type (attributes from the Worcester County original data) and 2) HSPF_ID. This process provided accurate information on how the Worcester County categories were reclassified into the HSPF land use categories (Table A2).

Table A2. “Classification” and “Type” attributes from the Worcester Co. land use database, assigned to the HSPF_ID categories.

Classification (Wo.Co)	Type (Worcester Co.)	HSPF_ID
1	Airport	1
1	Bare Ground	6
1	Basketball Court	1
1	Bike Path	1
1	Bikepath	1
1	Boardwalk	1
1	Building Footprint	1
1	Commercial_yrd	8

Classification (Wo.Co)	Type (Worcester Co.)	HSPF_ID
1	Dirt Road	2
1	Driveway	1
1	Parking Lot	1
1	Railroad	1
1	Residential_yrd	1
1	Residential_yrd	2
1	Rip Rap	2
1	Road Surface	2
1	Road median	1
1	Sidewalk	1
1	Swimming Pool	1
1	Swimming Pool	8
1	Tennis Court	1
1	Trail	2
1	Unpaved Driveway	2
1	Unpaved Road	2
2	Bay	4
2	Pond	4
2	River	4
2	Stream	4
3	Bare Buffer	6
3	Bare Ground	6
3	Borrow Pit	9
3	Brush	5
3	Cemetery	9
3	Commercial_yrd	8
3	Forest	5
3	Forest Median	5
3	Golf Course	9
3	Grass Median	9
3	Grassland	9
3	Park	9
3	Trail	9
3	Vegetated Buffer	5
3	Wetlands	4
4	Ag Operations	3
4	Agriculture Field	3
4	Bare Buffer	6
4	Bare Ground	6
4	Beach	6
4	Brush	5
4	Commercial_yrd	8
4	Dirt Road	9
4	Driveway	9
4	Forest	5
4	Grassland	9
4	Park	9

Classification (Wo.Co)	Type (Worcester Co.)	HSPF_ID
4	Parking Lot	8
4	Residential_yrd	9
4	Trail	9
4	Unpaved Driveway	9
4	Vegetated Buffer	5
4	Wetlands	4
5	Ag Operations	3
5	Ag Operations	7
5	Ag Operations	9
5	Ag Operations	10
5	Agriculture Field	3
5	Bare Buffer	6
5	Bare Ground	6
5	Brush	5
5	Commercial_yrd	8
5	Dirt Road	9
5	Driveway	9
5	Forest	5
5	Grassland	7
5	Industrial	8
5	Pond	4
5	Residential_yrd	1
5	Residential_yrd	9
5	Road Surface	8
5	Vegetated Buffer	5
5	Wetlands	4
6	Bare Buffer	6
6	Bare Ground	6
6	Brush	5
6	Commercial_yrd	8
6	Driveway	9
6	Forest	5
6	Forest Median	5
6	Grass Median	9
6	Grassland	5
6	Industrial	8
6	Residential_yrd	8
6	Vegetated Buffer	5
6	Wetlands	4

5. Using the dissolved process from GIS and the shape file Coastal_hspf_Intersect.shp, two attributes (Segment number and HSPF_ID) were selected for the calculation of areas by model segment (this data is not included in this report because of its size, but it is included in the final report of the watershed model).
6. The proportions of the HSPF land use categories in the Maryland Coastal Bays were calculated; note that the category of water has not been included in the

calculation of proportions and the areas corresponding to "chicken houses" has been added to the LIDI category. The percentage of impervious areas is the sum of HIDI plus LIDI (5%) while the proportion of urban pervious areas is the sum of HIDP plus LIDP (11%).

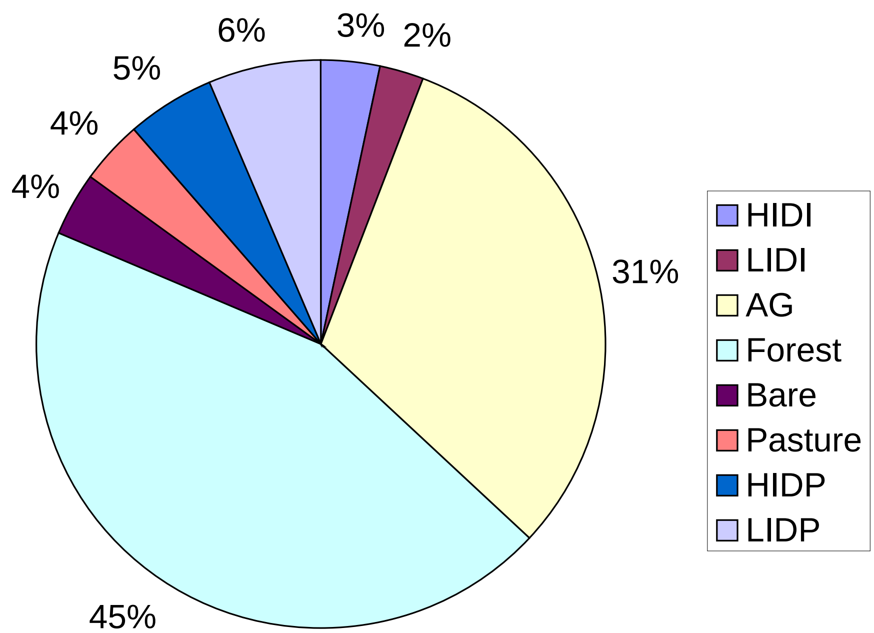

Figure A1: Proportions of land use within the Maryland Coastal Bays Watershed Model.

As verification, the areas of the two calibrated watersheds (Birch Branch and Bassett Creek) are presented below:

Table A3. Land use areas for Bassett Creek (Segment 143) and Birch Branch (Segment 144).

Segment	HSPF_ID[1]	Area (sq.meters)	(Acres)	Sq.miles	Total Area (Sq.miles)
143	1	18004.89	4.45	0.006952	
143	2	50371.28	12.45	0.019448	
143	3	2915590.42	720.46	1.125716	
143	4	18337.83	4.53	0.00708	
143	5	801295.88	198.00	0.309382	
143	6	33664.55	8.32	0.012998	
143	8	2731.31	0.67	0.001055	
143	9	57863.18	14.30	0.022341	1.504972
144	1	195204.23	48.24	0.075369	
144	2	280112.08	69.22	0.108152	
144	3	6871349.85	1697.95	2.653043	
144	4	169388.96	41.86	0.065401	
144	5	7482322.85	1848.92	2.888941	
144	6	192491.83	47.57	0.074322	
144	7	152832.35	37.77	0.059009	
144	8	367000.03	90.69	0.1417	
144	9	484378.67	119.69	0.18702	
144	10	67739.14	16.74	0.026154	6.27911

[1] See Table A1 for the description of the HSPF-ID categories.

From: Jeff White
To: angelicagmagness@gmail.com
CC: Chatham, Melissa; Panday, Nauth; Rule, Tim; Shi, Rou
Date: 3/9/2009 6:01 PM
Subject: Land Use QA/QC
Attachments: Mde_Umd_WoCo_comparison.xls

Angelica,
I have finished the land use QA/QC, and it appears as though the conversion of the land use from the Worcester County geodatabase to shapefile format did not alter the land use area calculations per model segment. First, as per Worcester County's preference that the calculations and analyses be performed within the context of the geodatabase provided to us, this could not have been done given the topology errors inherent within the database. Thus, given the state of the data, conversion to shapefile format was really the ideal way to perform the calculations.

It is possible that we could have fixed the topology errors manually, but this would have been too time consuming. Additionally, it is possible that we could have extracted those areas with topology errors and performed the analyses on the remaining data within the context of the geodatabase, but this also would have been time consuming, and furthermore, it would have been made difficult via problems in automatically extracting/querying this data due to the errors in topology.

Attached is a spreadsheet that compares the shapefile output and the geodatabase output. The geodatabase output was created from the revised geodatabase (Landcover_04_DRAFT_1_29_09_HSPF_acres_version92.gdb) that Worcester County provided us, which intersected the model segments with the land use and removed the HSPF Ocean City segments, which supposedly contained all or most of the topology errors. This revised geodatabase did not actually calculate the land use areas per model segment, it merely contained the spatial representation of the intersection, which means that the numbers you see in the attached spreadsheet had to be calculated from this revised geodatabase.

As you will also see, there are a few instances where the areas between the two segments are different; however, for the most part, these differences appear to be insignificant. Furthermore, in addition to this revised geodatabase containing the intersections between the segments and the land use, it appears as though the actual land use areas were updated as well. While I was reclassifying the segment-land use intersections to the HSPF model land use, I noticed some of the numbers per classification and type seemed to be different than the previous geodatabase your shapefile calculations were derived from. Thus, this may be the primary reason for the differences between some model segment-land use intersections. Additionally, the revised geodatabase was also missing certain data from the last geodatabase. For example, the "comments" field, which you had previously used in your reclassification (i.e., determining chicken house land use areas), is no longer included in the geodatabase. Thus, this is definitely contributing to the difference between the two data outputs, as the same areas could not be reclassified in the same fashion.

I think that it is safe to assume that the land use you are currently using for model calibration is the best output available given the constraints of the Worcester County land use data. Please let me know if you have any questions or if there are any further concerns, and if/how we are passing this information along to the county.

Thanks,

Jeff