Assessment Report of Delaware’s CHESAPEAKE BASIN

March 2001
Delaware Department of Natural Resources and Environmental Control
Acknowledgments

This report, compiled by the Department of Natural Resources and Environmental Control’s Chesapeake Basin Whole Basin Management team, represents a comprehensive assessment of the Delaware portion of the Chesapeake Bay drainage basin. This effort, overseen under the leadership of Steve Smailer, a senior hydrologist with the Division of Water Resources, challenged scientists, engineers, planners, and managers from throughout the Department to merge all the available environmental data and information about this basin into a single, comprehensive document.

The individuals that participated in this multidisciplinary initiative are to be congratulated for the time and talents that they devoted to this effort. The members of the Chesapeake team include the following:

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The Whole Basin Management approach developed by the Department of Natural Resources and Environmental Control (the Department) focuses on protecting Delaware’s environment by managing it in a comprehensive and coordinated fashion. Using major drainage basins as the chief management units, the Department is bringing together the expertise of all its divisions (Air and Waste Management, Fish and Wildlife, Parks and Recreation, Soil and Water Conservation, Water Resources, and Office of the Secretary) to assess, monitor, and protect the health of Delaware’s environment.

The basis for developing this report comes from the Department’s realization that virtually every activity that takes place in the environment impacts multiple resources or land-use activities. For example, improper disposal of hazardous substances on land can contaminate more than simply surface soils. Contaminants can leach into ground water or be transported to streams and other surface waters during storms, thus potentially affecting public drinking-water supplies, aquatic life, and recreational fishing. Additionally, abandoned contaminated sites challenge state and local governmental agencies to find ways to make these areas safe and attractive for industrial uses and other needs. Managing the complex and dynamic natural world we call “the environment” requires the Department to examine, from multiple perspectives, the many resources that comprise the environment.

1.1 DELAWARE’S DRAINAGE BASINS

The Department’s Whole Basin Management approach aims at managing all the biological, chemical, and physical environments of geographic areas in Delaware. These geographic areas have been delineated on the basis of drainage
patterns. As shown in Figure 1.1-1, four major drainage basins encompass the state: the Piedmont, Chesapeake Bay, Inland Bays/Atlantic Ocean, and the Delaware Bay and Estuary basins. Each basin consists of smaller management units, or sub-basins, known as watersheds. A watershed represents the area drained by a river, stream, or creek — in simplest terms, the area “shedding the water” to a given water body. There are 45 watersheds in Delaware.

Whole Basin Management utilizes a phased approach to effectively assess the health of a targeted basin, and to develop an implementation plan to address environmental problems (refer to Figure 1.1-2 and Table 1.1-1). The paramount objectives of the process are to protect the environment, improve relations within and outside the Department, maximize wise resource use, and promote environmental education and stewardship. For more information, see the Whole Basin Management Framework Document, available in the Department’s Office of the Secretary.

1.2 THE CHESAPEAKE BAY BASIN ASSESSMENT

The Chesapeake Basin is the second basin being assessed by the Department under Whole Basin Management. Figure 1.2-1 shows Delaware’s geographical location with respect to the Chesapeake Bay. The Delaware portion of the Chesapeake Basin is located in western New Castle, Kent, and Sussex counties. The Basin is named for the area into which it drains: the Chesapeake Bay. In Delaware, the Basin drains approximately 769 square miles and encompasses the following watersheds: Elk Creek, Perch Creek, Chesapeake & Delaware Canal, Bohemia Creek, Sassafras River, Chester River, Choptank River, Marshyhope Creek, Nanticoke River,
Gum Branch, Gravelly Branch, Deep Creek, Broad Creek, Pocomoke River, and Wicomico River (see Map 1.2-1 Chesapeake Basin Watersheds).

The Chesapeake Basin Assessment Report, written by the Chesapeake Basin Team, representing every division in the Department, depicts the current state of the Basin, issues of concern, and assessment needs.

The assessment phase required gathering and assessing existing information for the Chesapeake Basin from each division within the Department as well as from outside agencies. Specific goals of the assessment phase are contained in Table 1.1-1. This report should provide the “state of the environment” for the Chesapeake Basin. At a minimum, it should answer these basic, but essential, questions:

♦ What do we know about the Chesapeake Basin?
♦ What don’t we know?
♦ What do we need to know?

The report identifies immediate actions that may be taken to improve the Chesapeake Basin’s health and makes recommendations for additional or enhanced monitoring of specific environmental indicators. Additionally, the report identifies data trends and gaps, areas of programmatic overlap, initiatives that may be integrated, areas requiring additional focus, environmental stressors, and other findings germane to promoting management of the ecosystem. This assessment will serve as the catalyst for identifying and implementing priority recommendations — the next phase in the Department’s Whole Basin Management approach for the Chesapeake Basin.
2.1 GEOLOGY, SOILS, AND SEDIMENTS

2.1.1 INTRODUCTION

The Chesapeake Basin, the largest of Delaware's five drainage basins, encompasses a 769-square-mile area of land along the western border of the state. The Basin extends northward from the state's southern boundary line encompassing nearly half of Sussex County, crosses through the western third of Kent County, and continues up along the Mason-Dixon Line into northern New Castle County, almost to Newark, where it occupies a relatively narrow and small portion of the county (see Figure 1.2-1). Watersheds within the Basin discharge to river and stream systems that flow through the State of Maryland and into the Chesapeake Bay.

Regionally, this Basin occurs within the heart of the Delmarva Peninsula, which lies within the Mid-Atlantic region of the eastern United States. This region is characterized by a temperate, mild, humid climate (Engleman, 1985). According to National Weather Service stations in Delaware, long-term, monthly mean air temperatures throughout the Basin range from 30.8°F in January to 77°F in July. Average annual rainfall is approximately 45 inches (Johnston, 1976).

The elevation of the land surface in the Basin ranges from approximately 20 feet to 50 feet above sea level (ASL) in the southernmost portion of the Basin, to 50 feet to 80 feet ASL in the northern portion. Flat expanses and shallowly incised stream valleys characterize the southern portion of the Basin. The topography becomes more hummocky north of Smyrna, and streams are more deeply incised.

Like much of the Eastern Seaboard and most of Delmarva, the Chesapeake Basin is within the Atlantic Coastal Plain physiographical province. Approximately 96 percent of Delaware's land area lies within the Atlantic Coastal Plan, and the Chesapeake Basin falls entirely within this province. The Atlantic Coastal Plain is characterized by a relatively low, broad, and flat-to-undulating terrain consisting of a thick wedge of primarily unconsolidated sand, silt, and clay.

2.1.2 GEOLOGY AND HYDROGEOLOGY

More geological formations exist in the Chesapeake Basin than in any of the other three Delaware basins. Twenty-one sedimentary units have been mapped within the Basin. Seven of these units are exposed, or outcrop, at the ground surface (see Map 2.1-1 Surficial Geology). Most of the remaining units lie immediately below the surficial

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- Map 2.1-8 Soil Types
- Map 2.1-9 Septic System Suitability
units, or subcrop, at various locations within the Basin (see Map 2.1-2 Subsurface Geology). These units consistently dip to the southeast at a slope ranging from 15 feet to 90 feet per mile (see Map 2.1-3 Geologic Cross-Section). Older formations dip more steeply and subcrop beneath the younger formations (Talley, 1975).

To assist in the understanding and visualization of the Basin’s geology and hydrogeology, the following maps and tables are included:

- **Map 2.1-1 Surficial Geology** shows the locations of the most recent geologic formations that are exposed at the ground surface.
- **Map 2.1-2 Subsurface Geology** shows the locations of the subcropping or underlying geologic formations. This map illustrates what the geology of the Basin would look like if the surficial sediments were removed.
- **Map 2.1-3 Geologic Cross-Section** shows a cross-section of the geology of the Basin. Refer to either of the geology maps (Map 2.1-1, Map 2.1-2) to see the location of the A–A’ transect. The cross-section represents what the geology of the Basin would look like if it were cut and viewed along the cut face. The cross-section shows all of the 21 geological units that occur within 1,000 feet of the ground surface along an 82-mile path through the Basin. From this cross-section, aquifer thickness and depths to confining layers can be determined. Unconformities (periods of erosion or non-deposition) and faults are also indicated on the section. The locations of wells used to construct this cross-section are indicated using the Delaware Geological Survey well nomenclature.
- **Map 2.1-4 Hydrogeomorphic Regions** shows the geographic areas determined by certain physical features that greatly influence water-quality characteristics.
- **Map 2.1-5 Ground-Water Recharge Potential** separates the Basin into areas of differing infiltration rates. Categorized from excellent to poor, these regions show the relative ease with which rainwater, or any surface discharge, can enter the subsurface and thus the ground-water system.
- **Table 2.1-1 Geologic Properties** summarizes basic geologic information about formations depicted on Maps 2.1-1, 2.1-2, and 2.1-3. This table is organized according to the age of the unit and begins with the youngest sediments. The columns in the table are devoted to the following:
  - Age and name of the formation
  - Dominant lithology
  - Depositional environment
  - Resource value
  - Aquifer equivalent
  - Properties or facts
  - Aquifer formation
  - Aquifer type (confined or unconfined)
  - Area of resource value
  - Thickness
  - Transmissive properties
  - Quality
  - Ground water/surface water interactions
  - Properties or facts

These figures and tables will be referred to throughout the Geology and Hydrogeology Section. Location references for the occurrence of geological formations and areas with notable hydrogeological characteristics will be denoted by town locations that are shown on the maps. Unless otherwise noted, towns will be used to denote the approximate northern and southern extent of the physical feature or topic that is being described. For example, stating “The Calvert Formation subcrop area occurs in the area between Townsend and Viola” would specify the northern and southern extent, respectively, of the Chesapeake Basin’s Calvert Formation subcrop area.

### 2.1.2.1 Geology

**Physiographic Setting**

The Atlantic Coastal Plain province lies between the Mid-Atlantic Continental Margin to the east and the Piedmont province to the west and north. The mid-Atlantic Continental Margin is the offshore extension of the coastal plain and begins at the coast and extends hundreds of miles offshore. Crystalline rocks of the Piedmont province bound the Atlantic Coastal Plain to the west and north. The northern portion of Delaware’s Coastal Plain province begins at the Fall Line and extends southward where it reaches a thickness of approximately 8000 feet at Fenwick Island, Delaware. Coastal Plain geologic formations are composed of alternating layers of sands, silts, and clays that were deposited in various depositional environments over at least the past 120 million years. Many of these sand beds form thick ground-water aquifers that are utilized in Delaware.

Sedimentary deposits as thick as those of Delaware’s Coastal Plain are possible only under unique geologic settings. Delaware’s position along a once extremely active continental plate boundary has resulted in thick accumulations of sedimentary deposits. These sedimentary deposits
occur in a deep depositional basin known as the Salisbury Embayment. The center, and thus the thickest portion of the embayment, is located near Ocean City, Maryland (Sheridan and Grow, 1988). The sedimentary deposits thin as one moves away from the center of the Salisbury Embayment and travels north in the Chesapeake Basin, which is toward the embayment’s rim.

Progressively older subcropping and outcropping geological formations are encountered as one travels north in the Chesapeake Basin. Eroptive forces remove younger material in areas of the Basin where the elevation is relatively high, such as around and along the Basin’s rim. Removal of the younger surficial sediments leaves the underlying older formations exposed or less covered. In addition, relatively recent high-energy glacial streams, which flowed predominantly from north to south, eroded surficial sediments and have greatly contributed to the exposure of older formations in the northern portion of the Chesapeake Basin. Deposition in the low areas near the center of the Basin results in the formation of young sedimentary units, which cover older formations.

The stratigraphy, or series of geologic formations, changes relatively quickly when moving from north to south in the Basin (see Map 2.1-3 Geologic Cross-Section). This direction is essentially perpendicular to the strike of Delaware’s geological formations. In contrast, the geology remains more uniform when moving parallel to strike or in an east–west direction.

**Hydrogeomorphic Regions**

The U.S. Geological Survey (USGS) has characterized the Delmarva Peninsula into seven hydrogeomorphic regions (Hamilton et al., 1993). These regions are defined by physical features including topography, surficial geology, hydrogeology, and soil conditions. Of the seven regions, the following four are found in the Chesapeake Basin: inner coastal plain, poorly drained upland, well-drained upland, and surficial confined (see Map 2.1-4 Hydrogeomorphic Regions).

The inner coastal plain is located in the northern portion of the Chesapeake Basin between Townsend and Smyrna and comprises about 5 percent of the Basin’s land area. The poorly drained upland comprises approximately 80 percent of the Basin’s land area and lies south of the inner coastal plain. The well-drained uplands are found along the Nanticoke River and Broad Creek and occupy approximately 11 percent of the Basin’s land area. The surficial confined region occurs within the Walston Silt and upper Omar Formation and is found along the southern Delaware/Maryland border in the southernmost part of the Basin. This region covers approximately 4 percent of the Basin.

Hydrogeomorphic classifications are useful for identifying water-quality properties and patterns within a region. Each hydrogeomorphic region is characterized by specific water-quality characteristics. Therefore, hydrogeomorphic regions can be used as a tool to help identify water quality patterns (Hamilton et al., 1993). The USGS has related ground-water quality types and patterns to hydrogeomorphic regions.

**Stratigraphy**

**Older Subsurface Sedimentary Units**

The Atlantic Coastal Plain sedimentary units found within Delaware’s Chesapeake Basin rest upon pre-Mesozoic crystalline basement rocks that are older than 230 million years (m.y.) (Sheridan and Glow, 1988). The oldest sedimentary unit found within the Basin is the Lower Cretaceous-aged Potomac Formation. This formation comprises the bottom two-thirds of the Atlantic Coastal Plain sedimentary wedge or 4,750 feet (Sheridan and Glow, 1988). These sediments accumulated under fluvial or stream depositional conditions approximately 100 m.y. ago (Pickett, 1976). The dominant lithology types are silts and clays that were deposited within floodplains of ancient rivers. The sandy portions of this formation are river or stream channel deposits (Spoljaric, 1967a).

The Potomac formation was eroded during the early upper Cretaceous (approximately 90 to 100 m.y. ago) (Sheridan and Glow, 1988) as ocean water encroached upon the continent in response to a global sea-level rise. The sands of the Magothy Formation were deposited on top of the Potomac Formation and are the first marine sediments associated with this upper Cretaceous transgression, or sea-level rise (Pickett and Spoljaric, 1971). Full marine conditions persisted until about the middle Eocene (about 45 m.y. ago) and ended after the deposition of the Piney Point Formation (Pickett, 1976).

Even though full marine environments persisted from the upper Cretaceous until the middle Eocene, ocean levels rose and fell during the period which modified the types of sediments that were deposited (Johnston, 1973). These transgressive/regressive sea-level changes led to the deposition of the Merchantville, Englishtown, Marshalltown, Mt. Laurel, Hornerstown, Vincentown, and Nanjemoy Formations (Pickett and Benson, 1977). Most of these formations represent shallow to deeper shelf deposits. Some of these formations, especially the Hornerstown and Vincentown formations, are highly glauconitic (contains silicate minerals which are green and comprised of potassium, magnesium, and iron) and were primarily formed as a result of benthic organisms activity (Pickett and Benson, 1983). Midway between Smyrna and Dover, the Hornerstown, Vincentown, and Nanjemoy formations
become undistinguishable from one another, are grouped together, and are called the Pamunkey Formation (Pickett and Benson, 1983).

The Magothy Formation, a clean quartz sand, is found in the upper portion of the Chesapeake Basin. The Englishtown, Vincentown, and Piney Point formations are dominantly sandy while the Mt. Laurel Formation is dominantly a silty-sand. The Hornerstown Formation is variable in texture ranging from silt to clay with intervening silty-sand layers. The Nanjemoy Formation is primarily a silty-sand. The Choptank Formation is dominantly sandy while the Mt. Laurel Formation is dominantly clay but contains thin sandy beds. The Choptank Formation is primarily fine grained, composed chiefly of silt and clay (Pickett and Benson, 1977).

The seas retreated during the middle Eocene. From the middle Eocene to about the Oligocene Epoch (22 m.y. ago), there is no stratigraphic record of sedimentary deposits within the Basin. Likely, erosional processes dominated during this period (Pickett, 1976).

During Miocene time (beginning approximately 22 m.y. ago), the ocean levels rose and again transgressed across the Basin. The sea extended at least as far north as the Townsend area and was responsible for the marine deposits of the Chesapeake Group (Pickett and Benson, 1983). These sediments include (from oldest to youngest) the Calvert, Choptank, St. Marys, Manokin, and Bethany formations. Basal sandy silts of the Calvert Formation formed on the outer continental shelf while near-shore marine conditions formed the dominant setting for the upper sandy members of the formation (Pickett and Benson, 1983). Deposition of the Choptank, St. Marys, and Manokin formation occurred in a delta front to shallow marine setting while the Bethany Formation represents primarily deltaic deposits.

The Calvert Formation is dominantly a sandy-silt with sand and shell beds. The Choptank is dominantly sandy with shell beds and thick fine-grained muddy beds. The St. Marys is dominantly clay but contains thin sandy beds. The Manokin is dominantly a sandy unit that coarsens upward from a silty-clayey sand to a fine to coarse sand. The Bethany Formation is dominantly a sandy-silt to silty-sand with intervening layers of fine to coarse sand (see Table 2.1-1 Geologic Properties).

Younger Surficial Sedimentary Units

Younger and primarily sandy surficial formations blanket the underlying Chesapeake Group sediments and the older marine deposits. These units were deposited primarily under fluvial deltaic and estuarine environments south of Bridgeville. North of Bridgeville fluvial deposition dominated. With the exception of the southernmost portion of the Basin, the younger surficial units sit unconformably over the older formations. (An unconformity is the geological term applied to a break in the depositional history in a stratigraphic column due to either erosion or non-deposition). These surficial deposits become thicker in the southern portion of the Basin where they attain a maximum thickness of approximately 200 feet. In the northern portion of the Basin, these sediments are much thinner — less than 10 feet thick in many areas — or even entirely absent.

During the Pliocene Epoch (between 1.8 to 5 m.y. before present), deposition of sediments in the Basin began in the southern portion of the Basin with the fluvial to deltaic deposits of the Beaverdam Formation (Andres and Ramsey, 1995). These sediments cover most of the Sussex County portion of the Basin and occur from Delmar to just north of Bridgeville. Deposition of the lower portion of the Beaverdam Formation occurred under fluvial conditions while deposition of the upper portion occurred under deltaic conditions (Andres and Ramsey, 1995). In some areas, the lower unit of the Beaverdam Formation contains very coarse sediments (medium to coarse sand, gravelly sand, and sandy gravel with some cobbles and boulders reported up to 2 feet in diameter) that were deposited in high-energy rivers (Owens and Denny, 1979a). These fluvial systems likely eroded deeply into underlying sediments of the Chesapeake Group. The fluvial sediments of the bottom portion of the Beaverdam Formation are deeply weathered. This indicates that after deposition, the lower unit was exposed to the atmosphere for a relatively long period (Andres and Ramsey, 1995). Sea levels rose during the Pliocene Epoch resulting in the deposition of the upper unit of the Beaverdam Formation. This portion of the formation was deposited in a deltaic environment and is finer-grained than the lower unit. Sediment textures range from a fine-to-medium sand to a clayey-silt (Andres and Ramsey, 1995). The entire Beaverdam Formation (upper and lower units) is generally between 50 feet to 100 feet thick but may approach 200 feet thick in paleochannels located along the southern Delaware/Maryland border (Johnston, 1973).

In the southernmost portion of the Basin, estuarine conditions prevailed during the upper Pliocene Epoch when the Walston Silt was deposited. The dominant texture of the unit is silt and resulted from the erosion and weathering of older, exposed formations. The thickness of this formation ranges from approximately 10 feet to 30 feet (Owens and Denny, 1979b). The Walston Silt occurs just east of Delmar along the Delaware-Maryland Line (see Map 2.1-1 Surficial Geology).

During the Pleistocene Epoch (10,000 to 1.8 m.y. before present) meltwater from glaciers located as close
as 120 miles to the north in Pennsylvania formed massive rivers that flowed generally south into the region (Spoljaric, 1967a). These rivers eroded older marine and deltaic sediments, which at the time were exposed at the land surface. Erosion of these older surficial units occurred as far south as Bridgeville where the Beaverdam Formation becomes the surficial unit. Meltwater from glacial streams not only caused extensive erosion, it also brought massive amounts of sediments which covered the northern two-thirds of the Chesapeake Basin with medium to coarse sands of the Columbia Formation. The Columbia Formation contains gravel and silt beds and is the dominant surficial unit in Kent and New Castle counties. This formation is generally 20 to 30 feet thick in the northern portion of the Basin, and can reach a maximum thickness of 90 to 100 feet near its southern limit near Bridgeville. Columbia Formation sediments of 70 to 90 feet thick also occur in deeply cut channels paleochannels located southeast of Dover (see Map 2.1-1 Surficial Geology).

The Staytonville unit (a Pleistocene-aged deposit composed of clay and silty-sand and sandy-silt) was deposited on top of the Columbia Formation in the area between Greenwood and Harrington. The relationship of this unit to the underlying Columbia Formation is unclear. The unit may be an estuarine deposit. The thickness of this unit ranges from 20 to 40 feet (see Map 2.1-1 Surficial Geology).

Climatic changes during the Pleistocene Epoch resulted in at least four glacial/interglacial periods. Sea levels during the Pleistocene Epoch (also called the Ice Age) fluctuated in response to the advance and retreat of glaciers in the northern latitudes. Tremendous volumes of meltwater from glaciers caused sea levels to rise. As a result, major river valleys such as the Delaware and Susquehanna River were flooded (Owens and Denny, 1979a). Sea-level rise also drowned local river valleys within the Chesapeake Basin (such as the Choptank and the Nanticoke River). Sea levels during the last interglacial period (the Sangoan between 300,000 to 360,000 years before present) were approximately 25 feet higher than today. This transgression, during the Pleistocene Epoch, likely resulted in the deposition of other surficial estuarine units within the Basin. These include the upper portion of the Omar Formation and the Nanticoke deposits (see Map 2.1-1 Surficial Geology).

The upper Omar Formation is dominantly fine sand with interbedded silt, clay, and shell beds (Ramsey and Schneck, 1990). Lithological changes within this formation occur rapidly both vertically and horizontally. Some of the silt beds may be highly organic (Ramsey and Schneck, 1990). The total thickness of the Omar Formation is generally less than 25 feet in the Basin. This formation occurs in an extremely small area in the extreme southeastern part of the Basin.

Fine-to-medium sands of the Nanticoke Deposits occur along the Nanticoke River within the river valley and the river valley margins. This unit overlies the Beaverdam Formation and was likely deposited under fluvial conditions in the upper reaches of the Nanticoke River valley. Downriver, these sediments were likely deposited under estuarine conditions. The Nanticoke deposits are capped by sand dunes along the southeast side of the river. The deposit has a maximum thickness of approximately 25 feet (Andres and Ramsey, 1995).

The youngest sediments in the Basin are Holocene-aged and are primarily fluvial, swamp, marsh, and bog deposits. Deposition of these units began approximately 10,000 years ago and continues today (Andres and Ramsey, 1995). These sediments comprise a small percentage of the total sediment volume of the Basin and are scattered throughout the Basin along stream corridors and in wetland and bog environments. Tidal marsh deposits of the Basin are found only along the Nanticoke River and its major tributaries (see Map 2.1-1 Surficial Geology).

The lithology of the Holocene sediments is highly variable and ranges from organic, silty clays, to medium gravels. The marsh, swamp, and bog deposits are finer grained and more organic than the fluvial sediments. Swamp and marsh sediments range from 10 feet to 20 feet thick in the southern portion of the Basin. Bog deposits are generally less than 5 feet thick. These units overlie the Beaverdam Formation (Andres and Ramsey, 1995).

2.1.2.2 Hydrogeology

Ground water is to the sole source of drinking water throughout the Chesapeake Basin. Millions of gallons of ground water are withdrawn from the Basin’s aquifers on a daily basis. Within the Chesapeake Basin 15 of the 21 sedimentary formations are important as water supply sources and serve as aquifers. An aquifer is a transmissive body of water-bearing sediments or rock formation which are capable of yielding significant quantities of water. Both unconfined and confined aquifers are utilized as drinking water supplies in the Basin.

Unconfined Aquifer

The Basin’s unconfined aquifer system, also known as the surficial or water-table aquifer, occurs within the Columbia Formation and the Beaverdam Formation. The Columbia Formation covers the upper two-thirds of the Basin while the Beaverdam Formation covers the lower one-third of the Basin. Where the Columbia and Beaverdam Formations are hydraulically connected with older underlying sands, the unconfined aquifer becomes thick and includes other formations. In the southern portion of
the Basin, sands of the Beaverdam Formation and underlying sands of the Manokin Formation are hydraulically connected and form extremely productive aquifers capable of yielding large quantities of water. The unconfined aquifer reaches a maximum thickness of approximately 200 feet near Delmar, Delaware, where Pliocene-aged rivers cut deep paleochannels which resulted in thick accumulations of Beaverdam sands (Johnston, 1973).

In some areas, younger surficial sediments that function as confining or semi-confining units cap the Columbia and Beaverdam Formations. These units, the Staytonville Unit, the Walston Silt, and the upper Omar Formation, are generally less than 40 feet thick and locally confine the Beaverdam and Columbia Formations (see Map 2.1-1 Surficial Geology).

The unconfined aquifer is heavily utilized for supplying water to domestic, public, agricultural, and irrigation wells in lower Kent County and in Sussex County where surficial sediments are thicker.

The Columbia and Beaverdam formations not only function as productive aquifers, but also supply base flow to streams (Andres, 1994). Ground water from the surficial aquifer comprises a significant volume (on average as much as 75 percent of the total freshwater flow) of stream flow, particularly during dry periods. Thus, water quality in these aquifers can impact surface water quality.

**Water Source (Recharge)**

Recharging rainfall is the sole source replenishment for ground water in the unconfined aquifer system. On average Delaware receives 45 inches of rainfall per year. According to Johnston (1976), approximately 10 percent is discharged directly to surface water bodies through overland flow; 50 percent is evaporated or transpired by plants before reaching the water table. The remaining 40 percent infiltrate through soils and reach the water table. Evaporation and transpiration directly off of the water table accounts for an approximate 7 percent water loss. This means that only 33 percent (or 14 inches) of the total rainfall reaches the unconfined aquifer.

Rainwater moves into the ground-water system in recharge areas where permeable sediments enable the water to readily infiltrate. Most of the land area within the Basin is sufficiently permeable to be considered a recharge area. The Delaware Geological Survey (DGS) has been conducting ground-water recharge-potential mapping statewide. Mapping has been completed for much of the state including most of the Chesapeake Basin (see Map 2.1-5 Ground-Water Recharge Potential).

The main purpose for the ground-water recharge-potential mapping study is to categorize the ground-water recharge-potential of surficial sediments throughout Delaware. Categories include excellent, good, fair, and poor recharge potential. Based on the mapping completed thus far, excellent ground-water recharge areas are scattered throughout the Chesapeake Basin and occupy roughly 10 to 20 percent of the Basin area. Good recharge areas occupy 20 to 30 percent; fair recharge areas 50 percent; and poor recharge areas occupy less than 10 percent.

Most ground-water recharge occurs during the winter and early spring when evapotranspiration rates are low. Water tables of the unconfined aquifer systems respond to recharge and rise to their highest levels in late winter and early spring. Water tables are generally at their lowest levels during the period from late summer to late fall. Over the course of a year, the elevation between the seasonal-high water table and the seasonal-low water table ranges from 5 feet to 10 feet.

The seasonal-high water table of the poorly drained upland region is generally less than 5 feet below the ground surface (BGS) (Hamilton et al., 1993). Higher elevations and hummocky topography in the inner coastal plain region likely result in a lower seasonal-high water table. In addition, land along major stream corridors is often better drained and tends to have lower water tables. One of the lowest coastal plain water-table readings on record occurred just east of Middletown. At this location, the water table measured 35 feet BGS (Spoljaric and Woodruff, 1970).

**Ground-Water Flow**

Ground water moves much slower than surface water and follows specific flow paths as it moves through an aquifer. These flow paths vary in length depending on the thickness of the aquifer and the proximity of ground-water discharge areas (streams, rivers, ponds, bays, and oceans) where ground water enters surface water bodies. Ground-water flow paths within the unconfined aquifer of the Basin are relatively short, from hundreds of feet to less than 1 mile (Hamilton, et. al., 1993). The velocity of ground water along a flow path is slow, generally less than 1 foot per day. Age dating of ground water in areas located just outside the Basin indicates that most unconfined ground water is less than 50 years old (Hamilton, et. al., 1993).

Specific capacity (SC), transmissivity (T), and aquifer thickness indicate how readily water can move through an aquifer. The higher these values, the more productive the aquifer. These parameters vary widely from one locality to another, and such a range of values is reflective of the complexity and variable nature of the aquifer materials. The average SC and T values recorded for large-capacity unconfined wells are 27 gallons per minute per foot and 4,000 feet per day.
7,050 feet squared per day, respectively. These values range from 5 to 107 gallons per minute and 780 to 22,000 feet squared per day for SC and T respectively. The highest unconfined transmissivity value (22,000 feet squared per day) recorded in Delaware occurred in an area just east of the Basin between Harrington and Greenwood.

The highest well yield recorded in the Basin (1,400 gallons per minute) occurred in an irrigation well located west of Laurel. Based on information provided by Johnston (1973), yields from unconfined large-capacity wells located throughout and just outside the Basin averaged 668 gallons per minute. The lowest recorded unconfined aquifer well yield is 100 gallons per minute, which occurred in a well located just north of Middletown.

**Water Quality**

Ground-water quality within the Chesapeake Basin is highly variable. Much of the water in unconfined aquifers has been impacted by human activity at the surface. The confined aquifer contains natural contaminants and water quality that differs greatly from that of the unconfined aquifer. Ground-water quality variations within the unconfined aquifer are found in different geographical locations within a particular aquifer system. Water quality not only varies horizontally but also vertically with depth, especially within the unconfined aquifer. The ground-water quality of an aquifer is controlled by a number of factors. The dominant controlling factors include the composition of the sediments, the proximity of saltwater bodies, the aquifer oxygen content, rainfall composition, microbial activity, and the type, quantity, and concentration of introduced contaminants. The Basin's unconfined ground water can be broken down into two main water-quality groups: natural or non-impacted ground water and anthropogenically influenced or impacted ground water.

**Natural Quality Issues.** “Natural” ground water is often characterized by nitrate concentrations of less than 0.4 mg/l. These waters have not been impacted by land-use practices such as fertilizer application or wastewater disposal. This primarily occurs in areas where rainfall recharges through forested lands, or in the surficially confined hydrogeomorphic regions that occur in the lower portion of the Basin (see Map 2.1-4 Hydrogeomorphic Regions). Recharge through the surficial Staytonville Unit often results in a natural type ground water as well.

In general, natural unconfined ground water is often oxygen-rich, acidic, and soft (containing relatively little calcium and magnesium). The presence of oxygen leads to iron concentrations below the 0.3 milligrams per liter (mg/l) secondary drinking-water standard and to the absence of hydrogen sulfide. However, there are certain areas where oxygen is scarce (oxygen levels are less than 0.4 milligrams per liter) in the ground water, and dissolved-iron compounds and hydrogen sulfide are present and can cause significant natural ground-water contamination (Denver, 1986). In addition, other naturally occurring compounds such as manganese, sodium, chloride, calcium, magnesium, and total dissolved solids (TDS), can be found in the unconfined aquifer and often become problematic in the surficially confined hydrogeomorphic regions referred to earlier and near saltwater bodies.

**Human Impacts.** Agricultural activities (primarily the widespread application of nitrogen fertilizers) and the onsite wastewater discharge associated with residential and commercial development have significantly impacted ground-water quality over much of the Basin. In fact, because of its common occurrence, nitrate is often used as an indicator of impacted ground water. Nitrate concentrations in excess of 0.4 milligrams per liter indicate that ground water has been impacted by anthropogenic activities (Hamilton et al., 1993).

In addition to widespread issues like nitrate contamination, other site-specific contaminant problems exist in numerous locations throughout the Basin. Hazardous chemicals such as gasoline compounds from leaky tanks are being or have been released. In other areas, hazardous percolate from abandoned landfills continues to seep into the surficial aquifer. However, ground-water contamination associated with these sites is often localized impacting relatively small areas of the Basin.

Although both these widespread and local impacts exist, most ground water within the unconfined aquifer is still safe for drinking-water supply purposes. In many areas, nutrient concentrations are, however, above surface-water quality standards. Since ground-water supplies up to 75 percent of the total water volume in streams and rivers, nutrients found in discharging ground water are likely to contribute significantly to the eutrophication problems in some surface-water bodies.

**Nitrate.** A variety of sources (e.g. fertilizers, septic systems, atmospheric gases) can introduce nitrate, an oxidized form of nitrogen, into soils at the land surface. If this nitrate is not utilized by plants, it can enter the ground-water system. Where oxygen is also present, the nitrate can persist for long durations. Where oxygen is scarce, chemical reactions and natural microorganisms can convert the nitrate back into harmless nitrogen gas. Nitrate has a primary maximum contaminant level (MCL) drinking-water standard of 10 mg/l. Concentrations in excess of this are potentially harmful to humans. According to Hamilton and others (1993), approximately 20 percent of the ground-water samples taken from the Basin’s poorly drained upland hydrogeomorphic region exceed this standard. The Basin’s
poorly-drained upland hydrogeomorphic region comprises approximately 80 percent of the Basin’s land area (see Map 2.1-4 Hydrogeomorphic Regions). Ground-water sampling in this region also reveals that the unconfined aquifer has a median nitrate concentration of 4.4 mg/l (Hamilton and others, 1993). The well-drained upland region of the Basin likely has higher median nitrate concentrations due to the increased depth to the water table in these regions.

**Phosphorus.** Phosphorus concentrations in the unconfined aquifer are relatively low, averaging less than 0.08 mg/l (Denver, 1986). According to Denver (1986), phosphorus concentrations as high as 1.1 mg/l can be expected in areas with elevated pH. In areas where soils are oxidized and acidic, and contain high amounts of iron and aluminum, most phosphorus applied at the land surface becomes bound to the soil particles. In some areas, however, the ability of the soil to adsorb phosphorus has been greatly reduced due to over-application of fertilizer and/or wastewater. When this occurs, phosphorus is much more mobile and readily moves into and through the ground-water system. Unlike nitrate, phosphorus does not have a primary MCL and does not occur in high enough concentrations in ground water to cause a substantial health risk.

**Herbicides.** Like fertilizers, pesticide use is widespread throughout the Chesapeake Basin. Herbicides (e.g. atrazine, cyanazine, metolachlor, and simazine) are readily detected in shallow unconfined ground water beneath sandy soils with low organic matter. Atrazine is the most frequently detected herbicide and occurs at the highest concentrations (Denver, 1995). However, more than 95 percent of the herbicides detected are found at concentrations generally at or near the 0.1 microgram per liter laboratory-detection limit. In most cases, this limit is substantially below the drinking water standards set by the EPA.

**Confined Aquifers**

A confined aquifer is an isolated water-producing formation that is located between two distinctly less permeable formations. Numerous confined aquifers can be found throughout the Basin. In certain areas, overlying formations do not completely protect these confined aquifers. In these subcrop areas, a portion of the confined aquifer becomes part of the water-table aquifer and is vulnerable to contamination from surface sources.

Confined aquifers are utilized more often in the upper two-thirds of Kent County and in New Castle County where the unconfined aquifer is thin and where confined aquifers are closer to the ground surface.

Sandy units within the Potomac Formation (the deepest and oldest sedimentary unit in the Basin) act as a major confined water supply for many wells in New Castle County (see Map 2.1-3 Geologic Cross Section). Clays and silts of the Potomac confine this aquifer and separate it from the overlying sands of the Magothy, Englishtown, and Mt. Laurel Formations. The Magothy, Englishtown, and Mt. Laurel Formations provide water to many small domestic wells from the Chesapeake and Delaware Canal area to Middletown. South of the canal, larger production wells rely on the marine deposits of the Rancocas Group as an important water supply.

Although the confined Piney Point Formation is an important source of water elsewhere in the state, it is not used within the Chesapeake Basin. Silty clays of the Calvert Formation separate the Piney Point from the overlying Chesapeake Group aquifers. These clays are up to 100 feet thick in some areas and comprise an important regional confining layer. The Chesapeake Group contains extensive sand layers that are useful for water-supply purposes throughout most of the Basin south of Smyrna. Two of the lower sandy units, the Cheswold and Frederica aquifers, subcrop in the Smyrna to Dover area where they form the lower portion of the unconfined aquifer. The Federalsburg Aquifer, a third sandy unit, exists in the Dover area. This aquifer lies between the Cheswold and Frederica aquifers but does not subcrop beneath the overlying Columbia Formation.

Farther to the south, the Choptank Formation subcrops in the area between Viola to approximately 2 miles south of Greenwood. Sands of the Choptank Formation become thick enough to yield significant quantities of water south of the Harrington area where the aquifer is confined. This aquifer remains useful for water-supply purposes at least as far south as Laurel.

The St. Mary’s Formation confines and separates the underlying Choptank Formation from the Manokin and Bethany formations. These two formations subcrop in the lower-most portion of the Chesapeake Basin. The northern limit of the Manokin aquifer subcrop area occurs along a northeast trending line passing through Seaford and Bridgeville and extends south to the town of Laurel. The Bethany Formation is the southernmost subcropping unit. The lithology of this formation has not been adequately characterized in the Basin. In many locations, this formation is fine-grained and acts as a semi-confining layer for any underlying sands. In some areas, however, the Bethany Formation may be hydraulically connected to the overlying Beaverdam Formation and function as the lower portion of the water-table aquifer.

**Water Source (Recharge)**

Water in the unconfined aquifer recharges deeper confined aquifer systems. In subcrop areas, this recharge can
be relatively rapid. However, in areas where extensive confining layers exist, recharge to deeper confined aquifers can be extremely slow. These confining layers greatly reduce the ground-water flow velocity; subsequently, confined-aquifer water is often much older than that in the unconfined aquifer. In fact, water from the deepest confined aquifers can be thousands of years old and may have traveled several miles.

Water-Bearing Characteristics

Confined aquifers are generally less transmissive than unconfined aquifers. A comparison of confined and unconfined aquifer parameters in the Chesapeake Basin indicates that the average transmissivity for the confined aquifers is approximately four times less than that of the unconfined aquifer. However, the data supporting this conclusion are scarce and in some instances data from only one well were used to characterize an entire confined aquifer.

Information provided by Woodruff (1972, 1990), Andres (1994), and Sundstrom et al. (1975) indicates that the transmissivity of the various confined aquifers range from 187 to 5,481 feet squared per day. The highest values recorded occurred in the Piney Point Aquifer in the Dover area. The lowest values occurred in the Englishtown/Mt. Laurel Aquifer system near Middletown. Based on these data, the most transmissive aquifers (from highest to lowest) are the Piney Point, Choptank, Cheswold, Rancocas, Frederica and Potomac aquifers. Transmissivity values recorded for the various confined aquifers averaged approximately 1,675 feet squared per day.

Water Quality

Overlying fine-ground sediments protect confined aquifers from anthropogenic contaminants. However, confined aquifers may contain naturally occurring contaminants such as iron and hydrogen sulfide that are undesirable. A major reason for this is that confined aquifers have a relatively low oxygen content, which influences the geochemistry. Analyses of water-quality data compiled from USGS and DGS Reports indicate that confined aquifers, on average, contain roughly three times less oxygen than unconfined aquifers. Ground-water analytical data from Andres (1994), Woodruff (1970, 1972), Bachman and Ferrari (1995), Sundstrom et al. (1975), and Denver (1986) were combined and analyzed to determine minimum, maximum, and average concentration values for various parameters for each aquifer. The following statements regarding water-quality similarities and differences between the various aquifers are based on a comparison of this information. The number of available water-quality analyses varied greatly. For some confined aquifers, only very limited water-quality information exists.

Iron and Hydrogen Sulfide. Low oxygen levels result in geochemical reactions that favor the production of soluble iron compounds and hydrogen sulfide gas. Confined aquifer iron concentrations generally exceed the secondary drinking-water standard of 0.3 milligrams per liter (Bachman and Ferrari, 1995). Even though a drinking-water standard has not been established for hydrogen sulfide, this compound often becomes objectionable because of the rotten-egg smell it produces. Hydrogen sulfide commonly occurs in confined aquifers rich in sulfur-bearing organic material.

The Rancocas, Potomac, and Magothy aquifers contain the highest iron concentrations while the Chesapeake Group and Piney Point aquifers contain the lowest. In some localities, the Rancocas Aquifer has extremely high iron concentrations. Concentrations as high as 21 mg/l (the highest iron level found in any of the confined aquifers of the Basin) have been documented. Elevated iron levels within the Rancocas are probably related to the high percentage of iron-bearing glauconite. The Potomac Aquifer, with an average iron concentration of 3 mg/l, contains the highest average iron concentration found in the Basin. The Chesapeake Group aquifers contain the lowest average (0.02 milligram per liter) and the lowest maximum (0.75 milligrams per liter) iron concentration.

Nitrate. Nitrate, which is problematic and common in the unconfined aquifer, is not stable in aquifers with low oxygen levels and thus is usually not a problem in confined aquifers. In such settings, nitrate readily undergoes denitrification and changes into harmless compounds. Confined-aquifer nitrate levels are generally less than the detection limit of 0.02 milligrams per liter (Bachman and Ferrari, 1995).

Radon. Radon gas can be a problem in some confined aquifers. In adjacent states, this constituent has been identified in concentrations exceeding the primary maximum contaminant level of 300 picocuries per liter in the Englishtown/Mt. Laurel aquifers and in the Rancocas group aquifers. Radon is thought to be associated with glauconitic minerals found in these aquifers (Bachman and Ferrari, 1995). To date, radon has not been adequately characterized within the Basin.

Hardness/TDS. Hardness is a measure of the concentration of calcium, magnesium, and other dissolved solids contained in water. In Delaware, aquifers containing shelly, marine deposits can often have water-quality problems associated with hardness and TDS. Concentrations of these minerals are usually higher in confined aquifers than in unconfined aquifers. The highest levels in the Basin occur in the Chesapeake Group and Piney Point aquifers. Shell material and siliceous tests from saltwater diatoms
comprise a relatively high percentage of the sediments forming the Chesapeake Group aquifers and contribute silica to the ground water resulting in elevated TDS (Woodruff, 1970).

**pH.** The pH (hydrogen ion content) of confined aquifers is also generally higher than that of unconfined aquifers. The Piney Point and Chesapeake Group aquifers contain the highest pH levels, which average 8. Shell deposits, which buffer acidity, and the lack of acidifying reactions are largely responsible for the elevated pH values.

*Sodium and Chloride.* Sodium and chloride are the dominant constituents that limit the use of confined aquifers to certain areas of the Basin. Sodium and chloride become elevated with increasing depth. Many confined aquifers, such as the Potomac Aquifer, that have low salinity in the upper portion of the Basin lie too deep and become too salty to drink in the southern portion. In most areas, aquifers lying deeper than 800 feet below the ground surface become salty and non-potable. Around the Nanticoke River, however, the depth at which sodium and chloride becomes excessive is much shallower. A well (DNREC ID 91390) installed along the Nanticoke River at Woodland Ferry in 1992 yielded water with a salinity content of 0.4 parts per thousand and a specific conductance of 800 micromhos per centimeter. This well draws water from a depth of 360 to 380 feet below the ground.

2.1.3 SOILS

Soils are defined as a “collection of natural bodies in the Earth’s surface, in places modified or even made by man of earthy materials, containing living matter or capable of supporting rooted plants in the natural environment.” Its upper limit is air or shallow water. At its margin, it grades to deep water or to barren areas of rock or ice. Its lower limit, to the material beneath which is not soil, is perhaps the most difficult to define. Soil includes the horizons near the soil surface that differ from the underlying rock material as the result of interactions, through time, of climate, living organisms, parent materials, and relief. In the few places where it contains thin, cemented horizons that are impermeable to roots, soil is as deep as in the deepest horizon. More commonly, soil grades at its lower margin to hard rock or to earthy materials virtually devoid of roots or marks of other biological activity. The lower limit of soil, therefore, is normally the lower limit of biological activity, which generally coincides with common rooting depth of native perennial plants (Soil Survey Staff, 1975).

Advances in soil science have broadened the definition of soils to include soils that have formed in saturated conditions associated with open water. This broader definition will now allow soils that are under rivers, streams, estuaries, and other water bodies to be mapped and characterized. This characterization may be vital in the re-establishment of submerged aquatic vegetation and increased information about shellfish beds in many of the rivers within the Basin. In the Chesapeake Basin portion of Delaware, soil depth approaches its lower limits of the definition into the earthy materials devoid of biological activity.

Topography (relief) controls or modifies soil formation. Relief affects landscape distribution of soils, landscape distribution of moisture, erosion and alleviation patterns, temperature difference caused by aspect (the compass direction the slope faces), and combined temperature and rainfall effects as a result of elevation (Fanning and Fanning, 1989). Topography in the Chesapeake Basin is gently sloping in the northern part to nearly level going southward in the drainage Basin. Subtle differences in the landscape of 0.5 to 1.0 foot greatly affect the drainage of the soil. Surface-water runoff either collects in depressions or flows towards watercourses. The infiltrated water can discharge into depressions or flow down-gradient to upland head waters and streams areas. These depression and upland headwaters contain many of the wetlands in the Chesapeake Drainage Basin. The Delaware portion of the Chesapeake Basin occurs at the drainage divide between the Delaware River Basin and the Chesapeake Bay. Hamilton et al. (1993), also defined this area as the Poorly Drained Uplands. Tidal wetlands are found in the floodplains of the Nanticoke River and along the lower portions of Broad Creek. Most of these creeks and stream areas have been ditched for agricultural production and have lost many of their associated wetlands. Landscape changes caused by ditching within portions of the watershed, and channelization of the stream, can significantly alter flow volumes. Both of these practices will affect wetland hydrology, either by reducing the water supply available to the wetland or by increasing the speed in which the water flows through the wetland. In addition, these practices tend to increase sediment loads in the stream due to bank scouring and/or increased water velocities, which allows the stream to transport sediments longer and farther. About 65 percent of the land area in the Atlantic Coastal Plain have soils that are suitable for cultivation. The other 35 percent of the land area consists of soils that are not well suited to cultivation because of very poor drainage.

2.1.3.1 Hydric Soils

Soils are placed in natural drainage classes based on the correlation of mottles used to identify saturated zones within a soil associated with the seasonal water table. These mottles are indicators of seasonal high water tables.
and are found in soils where they are encountered. Mottles are actually the gray and red blotches that have formed in the soil from the interaction of soil bacteria, organic matter, and ground-water table. The ground water in saturated soils will quickly become oxygen deficient (anoxic); consequently, microorganisms will transfer the energy primarily to iron in saturated soils, which solubilizes the iron. The classes are based on the depth to mottling or gray colors, which indicate the maximum of the stable height of the water table. Significant portions of the soils that are found in the Basin are poorly to very poorly drained. Some of these soils would be considered hydric. Hydric soils are defined by the USDA Soil Conservation Service (1982) as “a soil that is either (1) saturated at or near the soil surface with water that is lacking free oxygen for significant periods during the growing season, or (2) flooded frequently for long periods during the growing season.” The following soils have a potential to be considered hydric: Berryland, Elkton, Fallsington, Hurlock, Longmarsh, Mullica, Othello, Pone, Portsmouth variant, Puckum, Tidal Marsh, Trussum, and Zekiah. Areas are considered to be wetlands when comprised of hydrophytic plants, hydric soils, and hydrology indicative of periods of continuous soil saturation during the growing season. A majority of these soils (see Map 2.1-6 Hydric Soils) are located within the headwater areas of the creeks and rivers. The headwaters and floodplain comprises 48 percent of the Basin.

2.1.3.2 Drainage

Improved drainage is one of the principal soil management needs of the Chesapeake Basin. Improved soil drainage has an increased benefit on agricultural production activities. Currently, there are approximately 1,500 miles of private ditching and 1,500 miles of publicly maintained tax ditches draining over 292,000 acres, which is 64 percent of the Basin. Only a few farms are located entirely on well-drained soils. These soils are chiefly in the upper part of the Basin and occur in areas that are higher in elevation adjacent to the Nanticoke River and its tributaries. Considerable acreage in the upper part of the Basin is being converted to residential development, which modifies soil drainage needs to storm-water management options.

Artificial drainage is needed in some degree in about 60 percent of the total acreage based on the soil types found in the Chesapeake Basin, or about 70 percent of the acreage suitable for crop production. Crop yields are often poor or crops fail completely unless a drainage system is well established, maintained, and controlled. This is especially true in the middle (Kent County) and lower part (Sussex County) of the Basin. Of the total acreage needing drainage, more than 70 percent is occupied by moderately well to very poorly drained soils. Very poorly drained soils occupy 43 percent (see Map 2.1-6 Hydric Soils) of the Chesapeake Basin acreage that needs intensive drainage to lower the ground-water levels. Soils that require intensive artificial drainage are Berryland, Elkton, Fallings, Hurlock, Long Marsh, Mullica, Othello, Pone, Pocomoke, Portsmouth-variant, Puckum, Trussum, and Zekiah. Moderately well-drained soils make up 13 percent of the remaining acreage needing less intensive drainage. Draining these soils may consist of only removing excess surface water. Soils that may require removing excess surface water are Hammonton, Ingleside, Keyport, Mattapex, and Woodstown.

2.1.3.3 Erosion

Most of the soils (95 percent) within the Chesapeake Basin (see Map 2.1-7 Soil Erodibility) are not highly erodible. Infiltration capacity and structural stability influence the inherent erodibility of a soil (K factor). The K factor varies from near 0.1 to about 0.6. Soils with low erodibility tend to be sandy and have K factors below 0.2. Soils with intermediate infiltration capacities and moderate soil stability have K factors of 0.2 to 0.3. Soils that are easily eroded have a K factor greater than 0.3. Less than 5 percent of the soil in the upper part of the Basin (New Castle County) tend to have low infiltration capacities and easily eroded surfaces. The Lenni, Keyport, Matapex, and Matapex are highly erodible (K factor > 0.4) because of the silty to fine sandy loam texture of the soil surface. With the high inherent erodibility of the soils in this watershed coupled with gently sloping terrain associated with Lenni-Matapex-Matapex soils, erosion can be a significant factor affecting surface-water quality. As stated previously, when new development projects (residential and commercial) are initiated, most of the soils are cut and graded, which makes them highly susceptible to erosion. Delaware’s erosion control regulations require areas that will not be worked (site disturbance) for at least two weeks to be stabilized. With Delaware’s rainfall pattern, a considerable amount of erosion can occur even with control measures.

The middle (Kent County) and lower (Sussex County) portion of the Basin have some of the least erodible soils found within the Chesapeake Basin (see Map 2.1-7 Soil Erodibility). Soil infiltration capacities tend to be higher due to the sandy texture of the soils found in both the moderately well and poorly drained soils. Moderately erodible soils make up 16 percent of the soil in the Basin with a K factor greater than 0.3, these soils tend to be located on dunal landscape positions and along stream terraces of the Nanticoke River and Broad Creek.
2.1.3.4 Characteristics of the Basin

Soils in the Chesapeake Basin are designated chiefly by two criteria: soil drainage class (excessively well to very poorly drained) and soil texture (sandy to clayey). Map 2.1-8 Soil Types shows 35 dominant soil types in the Chesapeake Basin. The soils map provides a general idea of the soils in the Basin, while providing the location of soils suitable or unsuitable with certain land-use activities (farming, septic suitability, wetlands, etc.).

Soils have been placed in natural drainage classes. As discussed previously, the classes defined from the correlation of mottles have been used to identify saturated zones with anoxic conditions and, thus, the seasonal water table. The classes are based on the depth to mottling or gray colors, which indicate the maximum of the stable height of the water table.

Excessively well-drained soils encompass broad areas of nearly level moderately sloping, dune-like ridges, some depressions, and steeper slopes bordering major streams (Nanticoke River) that are generally the sandiest in the Basin. This grouping of soils consists mainly of Fort Mott/Pepperbox (15.2 percent), Downer (5.7 percent) and Evesboro (0.6 percent). These soils have rapidly permeable subsoil of sand to sandy loam. Most of the soil areas have been cleared for crop production and residential home sites, but small areas remain in forest in steeper slopes along drainage ways.

In areas where high-value crops (processing vegetables) are grown, irrigation is commonly used as a supplemental water source. Most of the soils in this grouping are suited for residential (high septic suitability) and other non-farm uses, but their loose sandy nature are major limitations.

Well-drained soils occupy a large area that extends from the Chesapeake and Delaware Canal southward through New Castle County to the Kent County line. Small areas are scattered southward through Kent County and northern Sussex County on upland landscape positions. The soils in this grouping include Greenwich (3.2 percent), Hambrook (0.4 percent), Matapeake (3.3 percent), Rosedale (1.9 percent), Reybold-Hambrook (0.3 percent), Reybold-Sassafras (3.7 percent), and Sassafras (3.0 percent). These deep soils occur in upland areas that are nearly level to steep. The Matapeake, Reybold-Hambrook, and Reybold-Sassafras soils have a silt loam surface layer and silty clay loam subsoil. The Sassafras, Rosedale, Hambrook, and Greenwich soils have a sandy loam surface layer and a sandy loam and sandy clay loam subsoil.

Farming is the dominant land use on these soils; it is both intensive and extensive. The potential for farming the soils in this well-drained grouping is better than any other part of the Chesapeake Basin. Except for slope and the erosion hazard of the silty Matapeake and Reybold soils, these soils have few limitations for other land-use options (residential development, etc.). In New Castle County (upper Basin), the well drained soils are dominant soils used for residential development and have been experiencing the greatest loss of farmland in the southern part of the county.

This grouping of moderately well-drained soils consists of nearly level rolling uplands with some depressional landscape features separated by gently sloping ridges. These soils are scattered throughout the Chesapeake Basin, mostly in southern Kent County and northwestern Sussex County. This grouping of soils consists mainly of Hammonton (7.6 percent), Woodstown (4.3 percent), Ingleside (0.1 percent), Mattapex (0.1 percent), and Trussum (0.1 percent). These soils have a friable sandy loam to sandy clay loam subsoil. Many of these soil areas are associated with drainage ways and headwater areas. They are wet and slow to warm up in the spring, and in some places they are unsuitable for early crop planting. Ditches are needed in most nearly level areas for disposing of excess surface waters at planting time and during the growth periods of the crop. Except for slope and susceptibility to erosion in small areas, most of these soils have moderate limitations for most land uses. This grouping has a moderate suitability for septic systems because of a seasonal high water table during wet periods. The pressure-dosed septic disposal systems are the dominant system type used because this system maximizes the distance to a seasonal high water table. Residential development continues to occur in these areas even though septic systems fail at a 5 percent rate.

The poorly drained soil grouping occupies the greatest area (44 percent) of the Chesapeake Basin. These soils occur on mainly level or nearly level (less than 2 percent slope) upland flats and slightly depressional areas. Some of these soil areas have been cleared and are used for farming, but most of the areas remain as wet woodlands. The soils that occupy most of the area in this grouping are Fallington (17.5 percent), Pone (9.0 percent), and Hurlock (10.9 percent), while Berryland (0.6 percent), Lenni (1.0 percent), Mullica (0.7 percent), Othello (0.9 percent), Portsmouth (2.3 percent), and Zekiah (0.1 percent) make up the rest of the soils in the grouping. In all the soils other than Othello and Lenni, the surface layer is loam to sandy loam and the subsoil is strongly mottled, friable to firm sandy clay loam that is underlain by sands. Lenni and Othello soils have a silty surface layer and a silty clay loam subsoil through which water moves very slowly. For all uses, the chief limitation of these soils is the impeded drainage caused by clay in the subsoil.

Intensive drainage practices are needed on all of these soils because of the shallowness of the ground water.
After drainage is improved, the soils are well suited for crop production. Even if the soils are drained, the soils in this grouping generally have severe limitations that restrict their use for residential development and septic suitability.

2.1.3.5 Quality of Mapping
Soil survey data included in this assessment include a compilation of soils mapping from the 1960s to the present. The soils mapping for most of New Castle County except for a small portion of the Basin above the Chesapeake and Delaware Canal recently has been updated and incorporates most of the mapping conventions now employed by Natural Resources Conservation Service (NRCS). This mapping program is divided into soil mapping, description of those mapping concepts, and prediction of the behavior of these mapping concepts for various uses. Soil behavior relies on the evaluated and named soil properties (USDA, 1993). The current mapping techniques use planimetrically correct photography, which allows the data to be easily automated for natural resources geographic information activities. A digitized soil survey facilitates better land-use decisions concerning growth management and increased or sustained conservation of natural resources. It also provides users with soils maps made to a national standard that are easily registered with other digital maps. Soil databases link soil interpretations to digitized soil maps.

The current NRCS soil mapping program requires that most of these soil map units be field-verified using transects to quantify soil composition of individual map units. Most of the soils that are found within these individual map units have had representative samples characterized by laboratory analysis. The older soil surveys primarily focused on agricultural uses of the soil, and the soil mapping units were neither as controlled nor as defined. In the older surveys, the agricultural lands were mapped more accurately than urban or forestlands. This difference in mapping detail can easily be determined by comparing soil maps in agricultural lands to soil maps for forest or urban lands. Soil interpretations for forests and urban purposes are poor and are, at times, inconsistent with the intended use. Most of the soil laboratory data included in the old survey reports were from tests conducted on soils from adjoining states and not on soils within Delaware. Consequently, the quality and merit of the data may not be appropriate for some areas of Delaware.

Most of the soils in the Chesapeake Basin of Sussex County have been re-mapped under new NRCS standards, but the maps have not been digitized. The old Evesboro loamy sand and loamy substratum map unit originally occupied 127,580 acres in Sussex County. The updated survey separates this unit into 14 separate soil map units. The cost of digitizing the updated soil maps in Sussex County would be approximately 13.5 cents per acre or $84,500. One county in the state has estimated saving over $200,000 annually on one soil interpretation. The saving was generated in water and sewer pipe maintenance versus pipe repair. The maintenance is done based on pipe-corrosivity-soil-interpretation ratings.

Unfortunately, the only data that we have for Kent County is the old published soil survey. At the present time, it is unlikely that the Kent County Soil Survey will be updated very soon. The actual digitized soil maps for the Kent County data were obtained from a private consultant on a fee basis. Even though these maps are outdated and are not up to current standards, without them, the Basin assessment report would lack necessary information about hydric soils, septic system suitability, and general soil information within the Kent County portion of the Basin. Therefore, this soil information was assembled from all available sources in order to tie various sections of the report together in a relevant discussion of soils suitability and land use.

The GIS soil maps in the assessment are of various ages and quality. Using the new soil legends in Sussex and New Castle counties as the basis for an updated legend, the older soil mapping units from Kent and Sussex counties and the small area above the Chesapeake and Delaware Canal in New Castle County were re-coded as to the new, updated legend. This was done by using NRCS field review reports which discuss map unit composition, soil variability, and the best professional judgment and personal conversation of soil scientists with NRCS members who conducted the updates. Notwithstanding, the quality of the GIS maps presented can be debated and questioned, but at the scale presented, the errors correlating the old map units to the new updated units would be minimal, especially when these maps contain data from the updated New Castle County survey.

2.1.3.6 Suitability for Development
The Chesapeake Basin has one of the highest percentages (95 percent) of land area served by septic systems (see Map 2.1-9 Septic System Suitability). Thousands more lots exist that are currently undeveloped but are recorded and could be developed. Most of these undeveloped lots are stripped from farm-field frontages along county roadways and waterways. Overall, the Basin has moderate to severe limitations for on-site septic disposal due to the moderate (31 percent) to poorly drained soil conditions (48 percent) (see Map 2.1-9 Septic System Suitability). Systems that are suitable for the area range from gravity...
disposal systems (21 percent) to engineered pressure disposal systems (31 percent).

Siting a septic system is a three-step process. The first step requires a site evaluation. The site evaluation consists of investigating, evaluating, and reporting the basic soil and site conditions that are used to design on-site systems. Each report describes specific site conditions or limitations including, but not limited to isolation and separation distances, slopes, existing wells, cut and fills, and unstable landforms. Each report contains the type of on-site disposal system that must be constructed and assigned permeability. This siting procedure ensures that septic systems are located on the following soil properties: permeability, texture, structure, consistency, redoximorphic features, slope, and depth to rock, all of which may limit or hinder septic system performance.

The second step requires a licensed system designer to design the septic system required by the approved site evaluation and to obtain the approval of the Department. After the permit is approved, the final step is initiated. A licensed system contractor is hired to construct the system under the supervision of the Department.

Development will only continue within the Chesapeake Basin. It is expected that the number of septic systems will steadily increase because residential development is occurring throughout the whole Basin. It will not be possible to provide central sewer to all unsewered communities and locations. The Department developed evaluation criteria at the request of the Wastewater Facilities Advisory Council to determine the relative need and feasibility for central disposal either through sewer to treatment facility or through an on-site community disposal system. The evaluation criteria considers water-quality issues, other environmental issues, soils suitability for septic systems, septic system siting limitations, distance to existing sewers, cost-effectiveness of providing central sewer, and community well-being. These criteria were used to identify the unsewered communities with the highest needs. The Hartly area was the only community evaluated within the Basin. Based on the evaluation criteria, Hartly had only a moderate need when compared to 59 other communities statewide included in the feasibility assessment.

2.1.3.7 Suitability for Farming

The Chesapeake Basin is particularly favorable for agricultural production because the soils respond well to management, the temperate climate provides a fairly long growing season, and rainfall is well distributed. Currently, agriculture makes up 50 percent of the land use, forestry makes up 39 percent, and other land uses/urban development makes up the other 11 percent. General soil management practices are applicable to all or nearly all of the soils used for crop production in the Basin. These practices include draining the soils that are too wet part of the year or most of the year, applying the proper soil amendments (manure, commercial fertilizer, and lime), choosing suitable crop rotations, managing crop residue (cover crops), and irrigation.

2.1.3.8 Interrelationships

Current septic regulations deny the placement of standard (gravity and elevated sand mounds) and/or alternatively designed low-pressure pipe septic systems on soils where the seasonal high water table is within 20 inches of the soil surface. As an option for those property owners, the septic regulations allow for alternatively designed septic systems (Section 6.12010) on a case-by-case basis to be placed on some of these parcels. These alternative septic systems utilize technologies that pre-treat the effluent to a specific level, usually to levels below 10 PPM of nitrate-nitrogen. Total and fecal coliform levels are also significantly reduced within these pretreatment units. The soil must still dispose of the effluent generated. The cost of these pretreatment units has dropped significantly (from $12,000 – $15,000, to $10,000 – $12,000) so that more people can afford them. Consequently, a number of these units are being permitted (17 in 1994).

A problem arises on many of the parcels where alternative technologies would be utilized. These parcels are inherently wet and many are freshwater wetlands. In the past, several engineers have stated that when the water table is within 10 inches of the soil surface, it is difficult to get an elevated sand mound to work hydraulically. Thus, on parcels where the seasonal high water table is perceived to be within 10 inches of the soil surface, the Soil Assessment Branch has required that observation wells be installed to verify the depth to the seasonal high water table. If the water table is within 10 inches of the soil surface during the monitoring period, the parcel is considered unacceptable as a site for an alternative septic system. However, ground-water mounding calculations done by the Department system can be designed to hydraulically eliminate the effluent generated by these alternative systems when the water table is higher than 10 inches without significant mounding.

Most of these sites are located in wooded areas with hydrophytic vegetation indicative of wetlands. Most soils are hydric, and in many cases the wetland hydrology has been observed. These sites are jurisdictional wetlands as defined by the Clean Water Act and as delineated with the 1987 Army Corps of Engineers' Wetlands Delineation Manual. The Department allows these systems to be sited on these areas in accordance with Section 6.12010. In the past, on parcels considered to be freshwater wetlands, the property owner(s) was informed of the possibility that his parcel may contain jurisdictional wetlands and depending on the location of the wetland (i.e., isolated, adjacent or...
headwater), a permit from the appropriate federal agency may be needed. In most cases, the property owner does not notify the appropriate federal agency. Consequently, freshwater wetlands are slowly being lost to residential development one acre at a time.

Should the Department allow the development of the state’s wetlands regardless of the function of those wetlands? We have been allowing development because technology has overcome the limitations of the site hydrology as it relates to septic systems. Should we continue to allow this to occur simply because the technology exists? Conversely, by not allowing any development on lots deemed to contain freshwater wetlands, are we not “backdooring” a freshwater wetlands program through the septic system site evaluation program?

2.1.4 SEDIMENTS

The processes of erosion and deposition, whether resulting from geologic activities or from acceleration by human activities, occur when particles of soil, surficial material, and rock become detached as a result of the hydrologic (fluvial) processes of sheet erosion, rilling, and gully erosion. Mass wasting and the action of the wind (eolian processes) also contributes to sediment erosion and deposition. The characterization of sediment is, of course, closely linked to the geology, climate, and soils of a particular watershed. Relative differences in the ratio of silt, sand, and clay in the individual soil series determine their cohesiveness and, thus, their ability to resist erosive forces. Soils composed mostly of silt and sand will erode more easily, with heavier sands tending to settle out in the stream system and lighter sands and silts being deposited in ponds, lakes, and tidal outfalls. The eroded clays often stay in suspension, causing turbidity problems in the Basin’s water bodies.

2.1.4.1 Erosion

Soil erosion from upland areas is an ongoing natural process, and a certain amount of sediment bed-load transport is necessary to maintain stream stability. However, through man’s influence on the landscape, this process can be accelerated by orders of magnitude. As a result, the natural balance is upset, often leading to serious environmental degradation. According to information contained in EPA’s National Water Quality Inventory Report (1992), siltation is the most prevalent cause of impairment in assessed rivers and streams and is one of the five leading causes of lake impairment.

In the watersheds of the Chesapeake Basin, as in most watersheds, the more erosion-prone steeper slopes tend to be adjacent to the streams and their tributaries. This also occurs along the Nanticoke River and the Broad Creek, especially with the old sand dunes found along the Nanticoke River. In general, as the distance to a stream channel increases, the soil slope tends to flatten.

Where appropriate, soils were also mapped as being “moderately eroded” and “severely eroded” in their natural state during the course of the soil survey. Not surprisingly, the “severely eroded” soils were generally located on the steeper slopes adjacent to the tributaries. This can be seen graphically in the Map 2.1-7 Soil Erodibility. This map indicates that many of the soils within the Basin were mapped as being “moderately eroded.” The implication is, of course, that the eroded material ended up as sediment in the receiving waters.

Since the Dust Bowl, soil conservation has been a priority in the agricultural community. Though the intent has been to maintain productive land rather than to improve water quality, federal and state erosion control programs (voluntary) through the local conservation districts have been in place for many years. The federal Food Securities Act required all highly erodible lands to have a soil conservation plan developed and implemented by the end of 1994 if those farmers wished to maintain eligibility for future federal incentive programs. This only applies to lands classified as highly erodible. In Delaware, most lands classified as highly erodible are in New Castle County because of the slope and the silty soil surface in this area. Soil conservation management is otherwise voluntary.

Based on NRCS data, there are over 7,000 acres of highly erodible land (HEL) in the Chesapeake Basin based on soil mapping units and an erosion index greater than 8. These highly erodible lands correspond to those shown on Map 2.1-7 Soil Erodibility with a K factor of 0.4 or greater. Based on the total acreage in the Basin (453,760 acres): 43.8 percent of the acreage has a soil K factor of 0.0 – 0.19 (lowest potential for erodibility; 35.1 percent is rated as 0.2 – 0.29; 15.8 percent is rated at 0.3 – 0.39; and only 5.3 percent of the acreage in the Basin is rated as 0.4 – 0.49 (highest potential for erodibility).

2.1.4.2 Sediment and Nutrient Transport

While conservation tillage is very effective in reducing sediment loading to surface waters, it may not be as effective for improving overall water quality; it may actually increase loading of other pollutants. No-till requires increased use of pesticides and fertilizers. Those chemicals are not mixed into the soil. While the soil may stay in place, storm-water runoff may transport chemicals that are water soluble or attached to plant debris. Nitrogen and pesticide leaching also may increase. Using conservation tillage to control sediments may increase dissolved nutrient and pesticide transport. The role of tax ditches in delivering sediments warrants further exploration.
Maximizing the use of farm acreage is an incentive for farmers to forgo buffer strips along ditches and streams. Sediment loads from fields without buffer strips or grassed waterways can be dramatic.

As a physical pollutant, excessive accumulation of sedimentary material can fill streams and lakes to the point where they are no longer navigable. The acceleration of the erosion process started with the colonization of North America, as the native forest cover was removed and converted to agricultural areas or farmland. According to the DNREC Drainage Section, tax ditch systems typically undergo the removal of accumulated sediment in the channel bottom approximately every 15–20 years. The importance of agricultural drainage to nutrient transport from cropland to surface waters has not been investigated fully in Delaware or in most other states. This is partially because soil erosion and surface runoff have historically been viewed as the major mechanisms for nutrient losses to surface waters. The rather flat topography of southern Delaware suggests that erosion and runoff will be less of a factor in nutrient transport than in other Mid-Atlantic states. However, many fields in southern Delaware are farmed only because of the extensive ditch drainage system that exists in this area. The water table in these fields can be at or near the soil surface during the spring or following heavy rainfall events in summer. These ditches are extensions of the natural drainage system in the watershed and serve to drain the fields by capturing surface runoff and by lowering the water table. Little is known about the possible transport of phosphorus and nitrogen from agricultural fields to downstream surface waters via these drainage systems (Sims et al., 1996).

Moreover, since 1987, Water Control Structures (WCS) have often been installed in these ditches to artificially slow drainage, raising the water table beneath fields during the growing season in an effort to “sub-irrigate” crops. Research in other states has shown that WCS enhance water quality by reducing water flow and thus delivery of nitrogen and phosphorus to surface waters. Anoxic conditions created by these WCS may promote denitrification in soils, thus removing nitrate from shallow ground waters. However, previous studies in Delaware and in other regions have shown that phosphorus released from soils and sediments can be greater under anoxic conditions, resulting in increased concentrations of soluble phosphorus in drainage waters. Hence, a management practice installed to mitigate one environmental problem (nitrate contamination) may be creating or intensifying another (solubilization and transport of phosphorus). Analysis of agricultural drainage ditch waters conducted as part of a recent nonpoint source study in Delaware provided some support for this possibility. Total phosphorus concentrations in water samples from 17 ditches consistently exceeded values normally associated with eutrophication of fresh waters. Total phosphorus ranged from 0.01 to 0.03 milligrams per liter. In the spring, total phosphorus ranged from 0.21 to 6.14 milligrams per liter, from 0.04 to 1.14 milligrams per liter the summer, and from 0.04 to 0.85 milligrams per liter in the winter (Sims et al., 1996).

Given all the above factors, it seems apparent that more detailed information on the role of agricultural drainage, controlled or otherwise, is needed. Data on nonpoint source pollution of ground and surface waters by nitrogen and phosphorus are badly needed to aid in the development of management practices that improve ground and surface water quality in Delaware (Sims et al., 1996).

### 2.1.4.3 Dredging

Sedimentation has been an ongoing process within the Basin as evidenced by the fact that many colonial ship landings such as the town of Bethel are no longer accessible by larger watercraft. A more contemporary impact is the loss of water-carrying capacity in the streams of the Basin and their associated bridges, culverts, etc. This can lead to flooding problems and disrupt the transportation infrastructure. Keeping these streams and structures sediment-free requires constant maintenance in many instances, and this, of course, translates into public expenditures. Sediments that aren’t deposited in the streams themselves will tend to settle out in the ponds and lakes fed by those streams. For recreational ponds and lakes, surface area is often lost as the upper reaches sit in. In some cases, it may be necessary to remove accumulated sediments by dredging in order to restore recreational capabilities.

Historically, dredging operations within the Nanticoke River Basin have been conducted by the U.S. Army Corps of Engineers, Baltimore District. Most operations have been confined to the main stem of the Nanticoke River between its mouth at Tangier Sound/Chesapeake Bay, Maryland, and the bascule bridge (Route 13-A) at Seaford and Blades, Delaware. Also, two of the river’s tributaries, Marshyhope Creek (a.k.a. Northwest Fork, Maryland) and Broad Creek have been dredged. With the exception of Broad Creek, the Corps has continued to maintain navigable depths in these waterways because of the vital role they play in economic development and growth throughout the entire Basin (Williams et al., 1997).

During the 1980s, two maintenance-dredging projects were implemented by the Corps to alleviate shoaling conditions hindering commercial shipping activities in the Nanticoke River. In 1983, a project was undertaken to remove approximately 30,000 cubic yards of material from...
the Hawks Nest Shoal area of the main channel and from the section between Turtle Creek and the Seaford Harbor. A similar project was initiated in 1989–90 involving the dredging of over 50,000 cubic yards of material between Turtle Creek and the Harbor (Williams et al., 1997).

For both of the maintenance dredging projects identified above, Sussex County was responsible for providing the necessary confined disposal facilities (CDFs) to retain the material being dredged. In 1983, the county secured a 6-acre tract of upland near the Delaware-Maryland state line (area known as the Gum property), and in 1989, they secured a 25-acre tract of upland on property owned by the DuPont Company. Records of areas used for disposal before 1980 are not readily available, but there is speculation that Prickly Pear Island was created as a result of dredging activities in the downstream portion of the Nanticoke (Williams et al., 1997). See Map 2.3-2 Known and Potential Chemical Sources for the location of confined disposal facilities (CDFs) for dredge spoils.

2.1.4.4 Contaminated Source

Sediment has been identified as one of the major non-point source (NPS) pollutants due to its diffuse nature. Even though urban construction is the most intense source of erosion, agricultural activity has been identified as the leading source of sediment to receiving waters nationwide. This is probably also true for the State of Delaware as a whole. The Chesapeake Basin encompasses most of the agricultural areas in the state. Based on 1992 land-use data, all of the sub-watersheds of the middle and lower Chesapeake Basin exceeded (50 percent) in agricultural land uses.

Besides human impacts, sediment has serious physical impacts on aquatic ecosystems as well. It can cover the stream bottom, smothering fish eggs and bottom-dwelling organisms, which rely on the “nooks and crannies” provided by the natural bottom substrate. Sediment particles can abrade and accumulate on the gills of fish and other aquatic creatures, causing stress and death in some cases. Similar impacts can be observed in lakes and their associated ecosystems as well. It is generally accepted that deposition of sedimentary material and its attached nutrients is the major mechanism leading to the accelerated eutrophication of ponds and lakes. Submerged aquatic vegetation (SAV) is particularly susceptible to problems associated with excessive sedimentation. The act of removing accumulated sediments can itself have negative impacts, as wetlands and other aquatic ecosystems are disturbed in the process.

Some of the more serious environmental impacts associated with sediment come from chemicals that may hold onto the sediments. Individual sediment particles have a large surface area, and many molecules easily adsorb, or attach, to them. As a result, sediments can act as chemical sinks by adsorbing metals, nutrients, hydrocarbons, pesticides, and other potentially toxic materials. Indicator bacteria are also associated with runoff-borne soil and organic matter. Thus, areas of high sediment deposition sometimes have high concentrations of nutrients, persistent (i.e., long-lived) chemicals, and contaminants, which can be later released. Sediments that contain concentrations of constituents greater than those found in nature are classified as “enriched,” while those with concentrations of constituents which are not normally found in natural sediments are classified as “contaminated.”

According to the 1994 Delaware Watershed Assessment Report (also known as the 305(b) Report), bacteria is the most widespread contaminant in Delaware’s surface waters, but nutrients and toxics pose the most serious threats to aquatic life and human health. Many bottom-dwelling benthic organisms are filter feeders. As contaminated sediments pass through their bodies, some of the contaminants themselves can be absorbed into their body tissues. Since these organisms are often on the bottom tier of the “food web,” the contaminants can be passed on through the entire web, eventually reaching vertebrates such as fish. If higher vertebrates, such as birds and mammals (including humans), consume these fish in large enough quantities, there can be serious health consequences.

In December 1994, the Department conducted a study of sediment contamination in the Delaware portion of the Nanticoke River. The study featured a random stratified survey design and involved collection of five sediment samples from a 3.4-mile tidal reach of the Nanticoke above the City of Seaford and five sediment samples from a 3.2-mile tidal reach below Seaford. The study showed that the level of chemical contamination from sediments below Seaford is significantly greater than the level of contamination above Seaford. Metals proved to be the principal contaminants of concern based upon their detection at levels that may cause toxicity to benthic organisms. Bioaccumulative contaminants such as PCBs, dioxins/furans, and chlorinated pesticides were not detected at levels expected to pose a significant risk to aquatic life or human health (Greene, 1997).

Contaminants in the sediments below Seaford appear to be originating from land-based sources in Seaford as well as from sources above Seaford. Algae (fueled from excess nutrients) and other solids in the water column may serve to scavenge the contaminants from the water column and deliver these contaminants to the bottom through settling. More research is needed to characterize the complex relationship between pollutant sources, fate and transport, and ecological effects in the Nanticoke River watershed (Green, 1997).
The sediments above Seaforth were classified as sand, ranging in diameter from approximately 0.1 mm up to 1 mm. Below Seaforth, the sediments were composed of much finer (silt and clay) particles, generally ranging from 0.002 mm up to 0.075 mm. Specifically, smaller particles are more likely to be transported farther downstream than are larger particles. Smaller particles generally have a greater capacity to retain trace metals than do larger particles. In the case of the Nanticoke, we see that larger particles (with low pollutant-binding capacity) have settled out above Seaforth, while finer particles (with greater pollutant-binding capacity) have settled out below Seaforth (Greene, 1997). The finer particles absorb most of the contaminants and can carry them far from the original source.

The report, entitled Chemical Contaminants in Sediments of the Nanticoke River, states that riverbed sediments represent an important sink for many pollutants that enter the surface-water environment (Greene, 1997). Once incorporated into bottom sediments, these pollutants can pose a direct toxic threat to benthic-dwelling organisms and may also represent an indirect threat to human health through food chain transfer/bioaccumulation processes. In addition, re-suspension and diffusion of “in-place” contaminants can deliver significant quantities of toxics back to the water column, thereby representing an ongoing risk to the ecosystem and human health. The report also states that even sediment contaminants that are effectively sequestered due to deep burial or strong site-specific binding may become bioavailable when significantly disturbed by major storms or activities such as dredging and other channel modifications (Greene, 1997).

The Chesapeake Whole Basin Team should review and map out available pollutant source data for the area of the watershed above the Bridgeville gauge. The relative importance of these sources in comparison to sources in the Seaforth area should be considered within an overall mass balance context.

Based on statistical testing and nonbiased sampling design, the authors of the report safely conclude that the sediments below Seaforth are significantly more contaminated than the sediments above Seaforth. Simply because contaminants were detected at elevated concentrations in bed sediments below Seaforth does not mean that all of the contamination originated exclusively in the Seaforth area. It is quite feasible that part of the sediment contamination below Seaforth is due to complex fate and transport phenomena that act over the entire watershed, including the area above Seaforth. It may be that we do not see elevated levels of contaminants in the sediments above Seaforth simply because those contaminants are transported downstream in a dissolved state or as sorbed chemicals on colloidal particles. These contaminants may not settle out of the water column until they are scavenged by particles that are in the water near Seaforth. These particles could include, for instance, solids released from the City of Seaforth wastewater treatment plant, phytoplankton that have grown in response to excessive nutrient levels, or simply street dust that has entered the river as part of storm-water runoff. Contaminants delivered from the drainage area above Seaforth may not settle out until the salinity is high enough to induce classical coagulation/flocculation (Greene, 1997). Salinity levels in the Nanticoke River fluctuate significantly from season to season and from year to year. During the dry months of September and October, the salinity levels upstream increase substantially.

Research recently published as part of the Chesapeake Bay Fall Line Toxics Monitoring Program does in fact suggest that the area above Seaforth contributes to downstream transport of contaminants in the Nanticoke watershed (EPACBP, 1996). This work involved the collection of water samples from the Susquehanna River and eight major tributaries of the Chesapeake Bay, including the Nanticoke River. The Nanticoke was sampled at the USGS gauging station in Bridgeville, Delaware once in the spring of 1994 and again in the fall of 1994. The samples were analyzed for dissolved and particulate fractions of trace elements and organic constituents. Surprisingly, the Nanticoke had the highest Basin yield (i.e., mass per time per drainage area) for cadmium and zinc in both the spring and fall sampling efforts. In addition, during the spring survey, the Nanticoke also registered the highest Basin yields for nickel and pesticides such as simazine, gamma-BHC (benzene hexachloride), alpha-BHC, gamma-Chlordane, alpha-Chlordane, and p,p’DDE (dichlorodiphenylchloro-ethylene — a breakdown product of DDT (Greene, 1997).

The USGS and the State of Maryland are interested in conducting more extensive follow-up studies at the USGS Bridgeville gauge beginning in fiscal year 1998. It is suggested that the Whole Basin Management initiative should follow this work closely and review its files to determine if there are any obvious contaminant sources above the Bridgeville USGS gauge that might help to explain the results discussed above, including, for instance, federal or state Superfund sites.

The sediment study conducted in the Nanticoke River concluded through several assessment techniques that metals below Seaforth represent a potential risk to benthic organisms. In particular, arsenic, cadmium, mercury, nickel, and zinc were identified as potential contaminants of concern in these sediments. Furthermore, and surprisingly, silver emerged as a significant potential ecological stressor both above and below Seaforth. Equally surprising from this study were the moderately high levels of polyaromatic hydrocarbons (PAHs) detected below Seaforth and the extremely low frequency at which organochlorine pesticides were detected overall. As documented in the report
by Greene (1997), it was concluded that despite the moderate levels of PAHs, no adverse ecological or human health effects are expected from these compounds.

It was also shown in this study that the highly bioaccumulative compounds PCBs and dioxins/furans are not at levels that are likely to accumulate in the food chain to the point where they pose a significant risk to people who consume fish from the Nanticoke. This is an extremely positive finding in light of the popularity of fishing in the Nanticoke. The other positive finding in this study was the significant decline in lead levels from the concentrations detected back in the 1980s. Although dioxins and furans below Seaford were not at levels expected to cause a bioaccumulation problem, they were, nevertheless, slightly elevated above background levels for clean U.S. waters (Greene, 1997).

Finally, this study provides strong circumstantial evidence that toxic substances have been and continue to be released from land-based sources in the Seaford area. However, the results of this study cannot be used to conclude that all of the sediment contamination below Seaford is due solely to sources in and around Seaford. The quality of surface waters and their underlying sediments are strongly influenced by the activities that occur on the lands that drain to the water body. If chemicals are stored used, or disposed of within the watershed, there is a greater likelihood that those chemicals will find their way to the lowest spot on the landscape, which is the receiving stream. In general, urban land uses are associated with a greater number and variety of sources of toxics than are non-urban areas (Greene, 1997).

2.1.4.5 Interrelationships

As soil particles erode from the land surface and stream channels during rainfall events, they become temporarily suspended in the water column. From a water-supply perspective, this causes turbidity problems, increasing the cost of treatment. Due to their relatively large surface areas, these particles also have a high affinity for other chemically active constituents, such as metals and nutrients. If potential contaminant sources exist in the watershed, eroded soil particles can act as vehicles for transporting toxics to receiving waters. In high enough concentrations, these adsorbed constituents may cause surface water-quality standards to be exceeded.

Although limited in terms of the number of samples, the results of the Chesapeake Bay Fall Line Toxics Monitoring Program for the Bridgeville USGS gauge location suggest there are sources of eroded sediments that both carry pollutants and are pollutants. Pathogens, nutrients, and toxic substances are transported on sediments. Sediment erosion is both an urban and an agricultural problem. Where land is disturbed, erosion occurs.

Although urban construction is a temporary land use, active sites are the most intense source of erosion. Urban construction causes 10 times more erosion than the next competing source, farming.

Suspended soil particles also act as a source of stress on aquatic life, especially fish. Once the soil particles settle out of suspension and become sediment deposits, impacts to aquatic life are compounded. Bottom-dwelling organisms can pass contaminants in the sediments through the food web to higher organisms. In some cases this can preclude the consumption of fish from such waters. Thus a direct impact to living resources can lead to an indirect impact on recreational activities. Sediment can also have adverse impacts on habitat. The bottom substrate on which many organisms rely to live on and lay eggs can be completely covered with sediment. Wetlands can lose their habitat value and function through the same process.

Perhaps the single most important sediment cross-media link is that of land use. In a watershed with a completely wooded land cover, surface erosion is minimal and sediment transport in the stream system is in equilibrium. Once that cover is removed for agricultural production or for construction purposes, the land is exposed to accelerated erosion. Cumulative increases in impervious cover such as roof tops, parking lots, and driveways change hydrologic conditions such that streams become unstable and contribute to the sediment loading. Anyone attempting to mitigate the many negative impacts associated with sediment must recognize this link with land use.

Since the passage of the Delaware Sediment and Stormwater Law in 1991, all new construction activities that disturb over 5,000 square feet are required to have an approved sediment and storm-water plan unless specifically exempted. The program is delegated to various local agencies with oversight by the Department's Sediment and Storm-water Program and uses a “best available technology” approach to control nonpoint source (NPS) pollution associated with construction activities.

As part of the overall conservation planning process in the state, the local conservation districts, and the NRCS work with agricultural landowners in the Basin to develop and implement plans that are intended to reduce NPS pollution associated with agricultural activities.

Several federal cost-share programs promote conservation tillage. No-till has been very effective in Delaware. These practices may not be the best solution everywhere, however. No-till fields with heavy soils will not dry out fast enough in the spring. Where it is successful, farmers may not want to do it every year; fields are sometimes plowed every few years to break pest and weed cycles.
2.1.5 DATA GAPS AND RECOMMENDATIONS

1. Complete recharge-potential mapping for the rest of the state. This mapping shows areas where water and/or contaminants can rapidly enter the ground water.

2. Develop depth to ground-water maps for the entire state that highlight areas with an extremely shallow water table.

3. Support additional funding for updating statewide soil survey maps.

2.1.6 REFERENCES


2.2 DEMOGRAPHICS

2.2.1 INTRODUCTION

Delaware is the second smallest state in terms of land area at 1,309 square miles. As of the 1990 census, it was the seventh most densely populated state at 366.9 persons per square mile and the thirteenth fastest growing state. Household size was 2.59 persons per household, reflecting the national trend of falling household size. Population is projected to increase by roughly 142,000 persons between 1995 and 2020, to a total of nearly 860,000. The need to provide housing, infrastructure, and employment for these additional persons is likely to increase pressures on land and other resources. The established growth pattern in Delaware is a suburban sprawl that consumes much more land per capita, and is more costly, on a per-capita basis, than traditional mixed-use growth patterns.

Eleven percent of the state is considered urban, and less than 16 percent, rural. The remaining 73 percent of the state, with the exception of preserved agricultural, natural, and park land, is the rural-urban fringe where urbanization is proceeding. Urbanization in Delaware is stimulated by easy access to the eastern Boston-Washington, DC megalopolis and by comparatively lower land values and lower cost of living. According to Vaughn (1994), only four subdivisions in central Delaware along the western state boundary can be truly considered rural. These are the Felton, Harrington, and Kenton divisions of Kent County and the Bridgeville-Greenwood division in Sussex County. Of the towns in the Basin, the three largest are Georgetown, Laurel, and Seaford.

2.2.2 MAPS

2.2.2.1 Land Use

The land-use maps (Map 2.2-1 1984 Land Use, Map 2.2-2 1992 Land Use, and Map 2.2-3 1997 Land Use) summarize the data from the 1982, 1992, and 1997 Land Use – Land Cover surveys. For these maps, the Anderson Land Use Classification System was used to combined the various land uses into the following simplified categories to show their areal extent: Urban/Residential; Agricultural; Confined Feeding Operation; Brushland/Forest; Water/Wetlands; Barren/Other. It is important to note that some of the differences between the maps are artifacts of the different mapping procedures that were used. For instance, a 10-acre minimum mapping unit was used on the 1982 aerial photography, while a 4-acre minimum mapping unit was used in the interpretation of the 1992 and 1997 photography. A greater total acreage for wetlands is evident on the 1992 and 1997 maps (Map 2.2-2. 1992 Land Use and Map 2.2-3. 1997 Land Use) than on the 1984 map (Map 2.2-1. 1984 Land Use) because of the smaller minimum mapping unit size and new categories added to recognize “forested wetlands.”

2.2.2.2 Agricultural Preservation Districts

The Delaware State Legislature has made available tax incentives, regulatory tools, state funding, and intergovernmental coordination to preserve agricultural land. Most comprehensive plans identify currently farmed areas with good soils and designate them for continued agricultural use, but all too often, implementation of the plans is weak. Map 2.2-4 Agricultural Preservation Districts shows those lands that are currently enrolled in the state’s Agricultural Preservation Program.

When the possibility exists for extending sewer into a particular area, Delaware’s agricultural preservation program
is not an effective mechanism for protecting such land. Sewer availability is a strong incentive for selection of certain land uses, which are incompatible with permanent agricultural preservation. The Delaware Agricultural Lands Preservation Foundation is incorporated as a non-profit organization whose mission is to help preserve farmland. Some advantages of farmland protection include:

- Stabilizing the state economy because it is not affected by the same business cycles, labor strikes, etc., as manufacturing and other sectors;
- Low energy costs for transportation and production where large blocks of agricultural lands are preserved from urban sprawl;
- Smaller costs for public services and facilities;
- Recharge of ground-water systems;
- Recreation and scenic values;
- Cleaner air; and
- Preserving large blocks of farmland, providing a system of connected open spaces and sometimes habitats.

2.2.3 INFRASTRUCTURE-INDUCED GROWTH IN AGRICULTURAL AND CONSERVATION AREAS

Sewers affect land use by increasing the amount of land available for development. The extent of growth depends on the amount of vacant land the sewer serves and the sewer’s excess capacity. Sewers are built to manage waste and as a result maintain or improve water quality. However, sewers can lead to the conversion of large areas of land to residential development. This development, if improperly managed, can have numerous environmental impacts. Examples of these are erosion and sedimentation problems, flash flooding due to more impervious land cover, degradation of stream habitat, and increased air pollution (Council on Environmental Quality, 1976).

As with sewer areas, highway access is also a major stimulus for the suburbanization of rural areas. According to the Delaware Department of Transportation Capital Improvement Program, Fiscal Years 1999 – 2004, studies have been funded to determine the traffic needs/implications of the following:

- Harrington Truck Bypass;
- US 301 Major Investment Strategy;
- Sussex East/West Feeder Routes (SR 5, 9, 16, 18, 20, 24, 26 and 54);
- Laurel Bypass – Evaluation of East/West Traffic Flow;
- Seaford Bypass.

2.2.4 GROWTH MANAGEMENT STRATEGIES MAP

New development should be directed to where it makes the most economic, environmental, and social sense. The strategies for doing so are based on common-sense distinctions between highly developed areas, rural areas, and the transition areas between them. Although most decisions concerning land use remain at the local and county level, the state can influence the way development occurs through its spending and management policies. By making sensible decisions about building and managing highways, water and sewer systems, and other public facilities (commonly called “infrastructure”), the state can reduce the negative effects of unfocused growth.

By promoting development and redevelopment in places where adequate infrastructure exists or is planned, the state can reduce congestion, preserve farmland, enhance community character and protect important state resources. In short, it can preserve Delaware’s high quality of life. To do so, state agencies have to work closely with county and municipal governments. Map 2.2-5 State Investment Areas depicts the preferred areas for future growth within the Basin.

2.2.5 QUANTIFICATION OF NANTICOKE RIVER SELECT LAND-USE CHANGES

The Division of Water Resources is developing a strategy to identify riparian wetlands within the Nanticoke River watershed, which should be given priority acquisition status because of their relative natural resource values and their vulnerability to adverse impacts. A major portion of this initiative involves determining land-use changes within the watershed between the years 1982 and 1992.

Land-use types (uplands and wetlands) were mapped at a minimum mapping unit of 1 to 3 acres using a modified Anderson classification system through interpretation of 1982 and 1992 aerial photography. Land use types were digitized into a GIS which is being used to determine select land-use changes. Priority wetlands acquisition sites will be identified by integrating:

- Land-use trends which indicate areas of high, adverse land-use changes;
- Data on wetlands’ relative value; and
- The extent of wetlands protection (regulatory or via existing conservation acquisitions).

While this initiative focuses on identifying priority wetland acquisition sites, the land-use data and related analyses address a broad range of land-use types and has additional applications.

2.2.5.1 Trends

The following tables summarize land-use changes that have occurred since 1984.
### Table 2.2-1

**LAND USE/LAND COVER—CHESAPEAKE BASIN**

<table>
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</tr>
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<tbody>
<tr>
<td>Urban Built-Up</td>
<td>12,481</td>
<td>3%</td>
<td>29,114</td>
<td>6%</td>
<td>34,797</td>
<td>8%</td>
<td>146,833</td>
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<td>Agriculture</td>
<td>232,096</td>
<td>52%</td>
<td>244,869</td>
<td>50%</td>
<td>218,138</td>
<td>49%</td>
<td>-26,731</td>
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<tr>
<td>Confined Feeding Operation</td>
<td>509</td>
<td>&lt;1%</td>
<td>5,966</td>
<td>1%</td>
<td>6,536</td>
<td>1%</td>
<td>570</td>
</tr>
<tr>
<td>Brushland and Forest</td>
<td>199,151</td>
<td>44%</td>
<td>94,694</td>
<td>19%</td>
<td>86,052</td>
<td>19%</td>
<td>-8,642</td>
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<tr>
<td>Water and Wetland</td>
<td>3,292</td>
<td>&lt;1%</td>
<td>112,446</td>
<td>23%</td>
<td>100,698</td>
<td>22%</td>
<td>-11,478</td>
</tr>
<tr>
<td>Barren and Other</td>
<td>490</td>
<td>&lt;1%</td>
<td>1,704</td>
<td>&lt;1%</td>
<td>2,533</td>
<td>&lt;1%</td>
<td>829</td>
</tr>
<tr>
<td>Total</td>
<td>448,019</td>
<td>&gt;99%</td>
<td>488,793</td>
<td>&gt;99%</td>
<td>448,754</td>
<td>&gt;99%</td>
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### Table 2.2-2

**LAND USE/LAND COVER—NEW CASTLE COUNTY PORTION**

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<tbody>
<tr>
<td>Urban Built-Up</td>
<td>697</td>
<td>2%</td>
<td>2,977</td>
<td>8%</td>
<td>3,611</td>
<td>12%</td>
<td>614</td>
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<tr>
<td>Agriculture</td>
<td>18,487</td>
<td>62%</td>
<td>20,185</td>
<td>55%</td>
<td>15,662</td>
<td>52%</td>
<td>-4,523</td>
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<tr>
<td>Confined Feeding Operation</td>
<td>0</td>
<td>0%</td>
<td>80</td>
<td>&lt;1%</td>
<td>52</td>
<td>&lt;1%</td>
<td>-28</td>
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<td>Brushland and Forest</td>
<td>10,010</td>
<td>34%</td>
<td>5,049</td>
<td>14%</td>
<td>4,349</td>
<td>14%</td>
<td>-700</td>
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<tr>
<td>Water and Wetland</td>
<td>171</td>
<td>&lt;1%</td>
<td>7,519</td>
<td>21%</td>
<td>5,522</td>
<td>18%</td>
<td>-1,997</td>
</tr>
<tr>
<td>Barren and Other</td>
<td>251</td>
<td>&lt;1%</td>
<td>700</td>
<td>&lt;1%</td>
<td>863</td>
<td>&lt;3%</td>
<td>163</td>
</tr>
<tr>
<td>Total</td>
<td>29,616</td>
<td>&gt;99%</td>
<td>36,505</td>
<td>&gt;99%</td>
<td>30,059</td>
<td>&gt;98%</td>
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</tr>
</tbody>
</table>

### Table 2.2-3

**LAND USE/LAND COVER—KENT COUNTY PORTION**

<table>
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</thead>
<tbody>
<tr>
<td>Urban Built-Up</td>
<td>3,552</td>
<td>3%</td>
<td>7,425</td>
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<td>995</td>
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<td>141,372</td>
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<td>127,755</td>
<td>&gt;98%</td>
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2.2.6 POPULATION DATA

2.2.6.1 General Population Trends

New Castle County’s population is projected to rise by 85,428 persons, an increase of 19 percent, and 61,578 households, an increase of 37 percent, from 1990 to 2020. Kent County’s population is projected to rise by 32,137 persons, an increase of 28 percent, and 19,623 households, an increase of 50 percent, from 1990 to 2020. Sussex County’s population is projected to rise by 67,348 persons, an increase of 59 percent, and 36,318 households, an increase of 81 percent, from 1990 to 2020.

2.2.6.2 Census Data

Population in the Chesapeake Basin Study Area was measured through a GIS exercise using the 1990 census blocks with the Chesapeake Basin boundaries superimposed over it. Based on this exercise, approximately 63,000 persons live in the Chesapeake Basin.

Uncounted persons such as transient agricultural workers may introduce inaccuracies into population data and underestimate the magnitude of some localized environmental problems such as substandard housing, access to clean drinking water, and approved wastewater management.

2.2.7 REFERENCES


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### Table 2.2-4

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<td>310,916</td>
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**ASSESSMENT: DEMOGRAPHICS**
2.3 CONTAMINANTS ASSESSMENT

2.3.1 INTRODUCTION

For purposes of evaluating contaminants within the Chesapeake Basin, two broad categories, nutrients and chemicals, have been formed for presentation of this section. Specific nutrients discussed include nitrogen and phosphorus. Pathogens, which often occur in unhealthy numbers in the presence of high nutrients in surface waters, will also be included in the discussion of nutrients.

Chemicals are divided into classes, which include petroleum, solvents, and organics, pesticides and herbicides, PCBs, heavy metals, and other inorganics. Contaminants may enter the environment from a variety of sources. These sources include large industries, small businesses, agricultural operations, residential areas, and biological sources, as well as through the air transport of contaminants from outside the Basin. As the Chesapeake Basin in Delaware represents the headwaters of the various individual watersheds, water transport of contaminants from outside the Basin is not expected, with the exception of those waterways influenced by tidal action, such as the Chesapeake and Delaware Canal, and the Nanticoke River.

Some data contained within this section describe potential sources of contamination that, if left unmanaged or in the event of an accidental release, could have serious impacts on the environment. Other sources exist that are defined as potential sources because the Department does not currently possess information that definitively links a source to observable contamination. These potential sources may be considered possible or suspected sources.

Existing contamination may be the result of either past or present human activities. Past practices, such as landfill operations (now closed) and Superfund sites, may still be contaminant sources. Contamination from current activities may occur routinely, as in a permitted discharge of a municipal wastewater treatment plant; or may occur as a result of a spill or leak, as in ground-water contamination from a leaking underground storage tank. Contamination may be transported or exchanged between various media, such as a contaminant that was land applied that is subsequently transported in ground- or surface water.

The contaminant assessment that follows describes the various nutrient and chemical contamination sources that the Department has identified as existing within the Chesapeake Basin. These sources are grouped and presented as source types. As an example, landfills are considered a source type. Therefore, all landfills within the Basin are discussed under one heading. Under each source type, additional information is presented for those individual sources where contamination levels are of concern.
of each of these areas. Trends and/or data gaps within a source type also are identified. In order for users of this section to readily obtain additional information, each source type section includes an appropriate Department contact.

A database, called the Site Index Database, has been developed for known and potential contaminant sources within the Basin. A copy of this database is included on the accompanying CD-ROM. This database is designed to be an easy-to-update, central registry of contaminant site summary data. It is not intended to be a replacement for more detailed program-developed databases such as the Site Investigation and Restoration Branch’s Site Status Database, but rather to be an index to site data stored by the various programs in the Department. The database includes basic site identification information (name, ID number, XY location, basin), site type (e.g., underground storage tanks, spray irrigation sites, etc.), and a contact for more details about the site. Besides this basic information, the database also includes monitoring activity status and contamination potential ratings by media (soil, sediment, surface water, ground water) and contaminant class (nutrients, bacteria, petroleum, organics, pesticides, PCBs, metals, and inorganics) for each site. Database contents can be queried and displayed on-line through the database interface. Through the linking of the database with the GIS program Arcview, any number of sites can be plotted on a map. Using this database, it is possible to answer questions such as “Where are all the known PCB contamination sites in the state?” or, “Are there any contaminated sites near a proposed land acquisition area?” Chesapeake site data currently loaded in the database includes:

- Animal Operations;
- Combined Sewer Overflows;
- Dredge Spoils (Confined Disposal Facilities (CDFs));
- Hazardous Waste Generators;
- Landfills and Dumps;
- Large On-site Septic Systems;
- National Pollutant Discharge Elimination System (NPDES) Outfalls;
- Pesticide Loading, Mixing and Storage Facilities;
- Salvage Yards;
- State and Federal Superfund Sites (SIRB);
- Sludge Application Fields;
- Spray Irrigation Fields;
- Tire Piles;
- Toxics Release Inventory (TRI) Locations; and
- Underground Storage Tank (UST) Facilities.

In addition to these, the Department also has data/maps for houses with individual septic systems throughout the Basin and the state.

2.3.2 NUTRIENTS (NITROGEN AND PHOSPHORUS)

2.3.2.1 Category Definition and Characteristics

Nutrient enrichment of surface waters is a natural process, spanning thousands of years, resulting from natural erosion and the breakdown of organic material. However, activities linked to soil erosion, domestic waste disposal, and runoff can greatly increase the rate and amount of nutrients reaching waterways, accelerating the nutrient enrichment process (305(b), 1998). Nitrogen (N) and phosphorus (P) are the major nutrients that cause eutrophication of surface waters. Eutrophication is defined as an increase in the nutrient status of natural waters that causes accelerated growth of algae or water plants, depletion of dissolved oxygen, increased turbidity, and a general degradation of water quality. The enrichment of lakes, ponds, bays, and estuaries by N and P from surface runoff or ground-water discharge is known to be a contributing factor to eutrophication. According to the 1998 (305(b)) Watershed Assessment Report, nutrients pose a serious threat to water quality, aquatic life, and human health. Most nutrients are transported to estuaries and lakes by rivers and ground water. Agricultural runoff, urban runoff, and municipal and industrial point source discharges are the primary sources of nutrients.

2.3.2.2 Nitrogen

The soil nitrogen (N) cycle (Figure 2.3-1 The Soil-Nitrogen Cycle) is a conceptual summary of the interactions among the chemical and biological transformations undergone by N in the soil (Reeder, 1987). The key reactions for organic N sources include those that reflect the cycling of N between organic and inorganic forms (mineralization and immobilization); the gaseous losses (ammonia volatilization and denitrification); the losses associated with water movement (leaching and erosion); the symbiotic process of biological N fixation; and plant N uptake and subsequent removal in the harvested portion of crops. Many of these reactions are controlled by soil microorganisms which alter the form, oxidation states, and thus the fate of N, among N₂, N₂O (nitrous oxide), NH₃/NH₄⁺ (ammonium/ammonium), NO₃⁻ (nitrate), and NO₂⁻ (nitrite). The relative importance of these reactions varies with soil and environmental conditions. Nitrate leaching is a major concern in humid regions (such as Delaware) where excessively well-drained soils overlie shallow water tables (Sims, 1995).

Mineralization

Mineralization refers to the conversion of organic forms of N (proteins, amino sugars and nucleic acids) to ammonium-N (NH₄⁺). Heterotrophic soil microorganisms that use the organic N as an energy source for their metabolism mediate the process. Once mineralized,
NH$_4$+ can be nitrified, or converted, into nitrite (NO$_2^-$), and then nitrate (NO$_3^-$), by the actions of chemoautotrophic bacteria that are obligately aerobic, obtaining their carbon from CO$_2$ and their energy from the oxidation of NH$_4$+ (ammonium). Immobilization represents the reverse reaction, and involves the assimilation of inorganic N (NH$_3$, NH$_4$+, NO$_2^-$, NO$_3^-$) by soil microorganisms, and the transformation of these mineral forms of N into the organic compounds that constitute microbial biomass (Sims, 1995). The balance between these two biological reactions (mineralization and immobilization) determines the amount of plant-available inorganic N in the soil matrix.

Environmental factors controlling mineralization, nitrification, and immobilization reactions, as well as the soil itself, must be understood to ensure optimal quantities of available N when organic N sources are used as a fertilizer. As these processes are controlled by soil microorganisms, all parameters that affect biological activity (temperature, moisture, aeration, and soil pH) will influence the rate and extent of these three N transformations (Sims, 1995). "Optimum" conditions for these transformations have been broadly defined and vary slightly between mineralization-immobilization reactions and nitrification. For mineralization, optimum conditions are a temperature range of 40° – 60°C and a soil moisture content of 50 – 75 percent of soil water-holding capacity. For nitrification, optimum conditions occur when temperatures are 30° – 35°C, moisture content is 50 – 75 percent of soil water-holding capacity, and the pH value is between 6.0 and 8.0 (Sims, 1995).

**Ammonia Volatilization**

Ammonia volatilization refers to the loss of NH$_3$ from the soil as a gas and is normally associated with high free NH$_3$ concentrations in the soil solution and high soil pH. The most successful approach to reduce NH$_3$-N volatilization from organic wastes has repeatedly been shown to be rapid incorporation with the soil. For example, only 10 percent of the added NH$_3$-N was lost when poultry manure was incorporated immediately, as compared to a loss of 56 percent when it was incorporated after three days (Sims, 1995).

**Denitrification**

Denitrification is defined as the reduction of NO$_3^-$ to a gaseous form of N, by chemoautotrophic bacteria. As with all microbial reactions, denitrification is influenced by carbon (energy) availability, temperature, aeration/moisture, and soil pH. Amending soils with organic wastes generally increases the potential for denitrification losses of N (providing nitrification of organic N has occurred) because wastes provide available carbon and increase soil moisture-holding capacity.

Nitrogen can also be transported from organic waste-amended soils into ground water by leaching and to surface waters by erosion or runoff. Losses of N by leaching occur mainly as NO$_3^-$ because of the low capacity of most soils to retain anions. In general, any downward movement of water through the soil profile causes leaching of NO$_3^-$, with the magnitude of loss being proportional to the concentration of NO$_3^-$ in the soil solution and the volume of leaching water (Sims, 1995). Nitrate that leaches below the crop-rooting zone represents loss of a valuable plant nutrient, and hence an economic cost to agriculture. If the nitrate enters ground water, two major environmental problems can occur. The consumption by humans or animals of drinking water with high nitrate levels has been associated with several health problems, the most serious being methemoglobinemia (oxygen deficiency in blood) in infants. Additionally, ground water with high nitrate levels that discharge into sensitive surface waters can contribute to long-term eutrophication of these water bodies. The setting most conducive to NO$_3^-$ (nitrate) leaching and ground-water pollution is a sandy, well-drained soil, with shallow water table, in an area that receives high rainfall and frequently applied fertilizers, manures, or other N source material (Sims, 1995). However, any situation involving overapplication of wastes and/or fertilizers, or intensive irrigation, has the potential to cause significant NO$_3^-$ leaching, regardless of soil and climate (Sims, 1995).
According to Johnson (1976), ground water may contribute as much as 80 percent of the total flow in shallowly incised streams. Ground water also supplies most of the drinking water in Kent and Sussex counties. Chemical fertilizer, manure, and septic system leachate are major sources of ground-water nitrate contamination in Delaware. As evidence, researchers have noted a link between agricultural land activities and elevated ground-water nitrate levels (Ritter, 1984, 1992; Denver, 1989). Also, intense poultry production has been associated with elevated nitrate levels (Andres, 1992). Finally, septic tanks have been identified as a localized source of nitrate, especially when numerous systems are concentrated in an area (Denver, 1989). Provided a source of nitrate exists, a more critical factor is soil type and depth to water table (Ritter, 1984; Andres, 1991; Denver 1989; Bachman, 1984). Even if nitrate sources are extensive, areas with poorly drained soils do not tend to have high nitrate levels in ground water. Low oxygen conditions in poorly drained soils allow for greater denitrification so that nitrogen is lost to the atmosphere rather than leached into ground water.

Erosion

Erosion refers to the transport of soil from a field by water or wind. Surface runoff is the water lost from a field when the rate of precipitation exceeds the infiltration capacity of the soil. Both processes can transport soluble inorganic N and organic N to surface waters and contribute to the process of eutrophication or to drinking-water contamination. Several watershed studies have shown that most of the N lost by erosion or runoff is sediment-bound organic N (Sims, 1995). Although the solubility of NO3− favors its loss in runoff as opposed to sediment transport, total N losses from most watershed studies are usually several-fold greater than soluble N.

Surface applications of organic wastes are undesirable because they increase the likelihood of soluble and organic N losses by erosion and runoff. In agricultural operations, conservation practices designed to conserve soil by reducing tillage may involve applying manure to soil surfaces. Surface application of manure also occurs when farmers apply manure during winter months, when the soil is frozen and easily traversed by heavy equipment. The use of grassed waterways or filter strips that trap sediment and accumulate soluble N in plant biomass can help reduce N losses in these situations (Sims, 1995).

2.3.2.3 Phosphorus

Phosphorus (P) is an essential plant nutrient and vital for the successful production of agronomic crops. It is essential for most physiological processes in plants, such as photosynthesis, energy transfer, genetic regulation of cell division and growth, and the production of seeds and fruit (Sims, 1996). If soils are deficient in P, plants may become stunted, with poorly developed root systems. As a result, significant reductions in yield may occur. Studies show that long-term application of animal wastes to soils increases phosphorus levels well beyond the amount needed for effective crop production (Mozaffari and Sims, 1994). Phosphorus contributes to eutrophication by entering surface waters via erosion (sediment-bound P), runoff (soluble inorganic and organic P), or subsurface flow. Accordingly, accumulated levels of soil P must be reduced, and transport of soluble or sediment-bound P to sensitive water bodies needs to be inhibited.

Bioavailable phosphorus (BAP) (either dissolved or particulate form) in agricultural runoff can promote freshwater eutrophication (Sharpley et al., 1994). While dissolved phosphorus (DP) is immediately available for uptake by aquatic biota, a variable portion of particulate phosphorus (PP) represents a secondary and long-term source of BAP in lakes (Sharpley, 1993). Dissolved P in runoff originates from the release of P from a thin zone of surface soil and vegetative material. Particulate or sediment-bound P is associated with soil and vegetative material eroded during runoff. Bioavailable P includes DP and a portion of PP that is in equilibrium with DP and available for algal uptake.

Crop production systems are forced to continually use manure as fertilizer because of the lack of economically viable alternatives for manure disposal. As a result, these systems almost always build soil P levels well beyond ranges considered optimum for most agronomic crops. The unfavorable N:P ratio in most manures results in over-application of manure P relative to crop P needs. Consequently, soil test P has accumulated to levels that are of environmental rather than agronomic concern (Sharpley et al., 1996).

Phosphorus is retained in soils by several mechanisms, collectively referred to as “P fixation.” Phosphorus can also be immobilized in an organic form if the C:P ratio of an added organic material is high (normally greater than 300:1). The primary soil constituents involved in P retention are the hydrous oxides of iron (Fe) and aluminum (Al), the alumino-silicate minerals, soil carbonates, and soil organic matter. Amending soils with manures, litters, or other organic wastes has been shown to affect the adsorption-desorption process for P.

In animal wastes, phosphorus is found in both organic and inorganic forms (e.g. >50 percent of phosphorus in poultry litter can occur as inorganic phosphorus) (Goggin et al., 1997). Organic forms of phosphorus are slowly converted to soluble, inorganic forms (Mozaffari and Sims, 1996). In fact, phosphorus from animal waste is probably used by plants as efficiently as that provided in a broadcast, inorganic fertilizer. Most (>70 percent) of the phosphorus in
Delaware soils is fixed by aluminum or iron in forms that are only slowly available to plants (Mozaffari and Sims, 1996; Vadas, 1996).

In contrast to nitrogen, phosphorus levels are low in ground water, even in agriculturally affected ground water (Denver, 1989). Ground water is not considered a phosphorus-loading pathway. Phosphorus is lost from agricultural fields in either a soluble form dissolved in surface runoff and subsurface, laterally flowing water, or a particulate form bound to eroded soil particles or organic matter. Dissolved phosphorus can either leave a field in surface runoff; move through the soil and leave a field in subsurface, laterally flowing water; or percolate into the soil where it may eventually leave a field in water drained by tile drains or drainage ditches. Under low-oxygen conditions, iron-bound phosphorus may be released from sediments. Also, organically bound phosphorus may be released when biota consume organic matter in the sediments. Historic erosion is the likely source of stream and lake-bed sediments which currently may be releasing phosphorus.

The Total Maximum Daily Load (TMDL) Regulation for the Nanticoke River and Broad Creek within the Chesapeake Basin call for nonpoint source nitrogen loads to be reduced by 30 percent and for nonpoint source phosphorus loads to be reduced by 50 percent from the 1992 baseline.

2.3.2.4 Bacteria (Pathogen Indicators)

As the name implies, indicator bacteria are indicators of pathogenic (disease-causing) bacteria and viruses. Sources of indicator bacteria (enterococcus and coliform) are widespread. Sources of most concern are those of human origin such as raw or inadequately treated sewage. Wildlife and animal operations such as feedlots can also be significant sources of indicator bacteria, although they represent less of a risk to human health compared to human wastes (Watershed Assessment Report [305(b)], 1998). High levels of bacteria pose an increased risk of illness to shellfish consumers, swimmers, and others who may come in contact with contaminated waters.

A quantitative measure of indicator bacteria in ambient water is performed semi-monthly at numerous sites within the Basin. Delaware uses a standard of 70 total coliform bacteria per 100 ml (running geometric mean); and fewer than 10 percent of samples may not exceed 330 total coliform per 100 ml.

Indicator bacteria are reflective of a concern for a variety of human enteric viruses, various other unclassified viruses, shellfish diseases, and bacterial pathogens.

At present, the Total Maximum Daily Load (TMDL) concept has been applied in Delaware only to marinas vis-à-vis indicator organisms. The concept is based on theoretical loading of bacteria that could indicate the presence of disease. The potential daily pathogen output from one person’s untreated sewage could equal that of treated sewage from hundreds to possibly thousands of people (depending on the level of treatment). The boat/marina-related TMDL concept assumes zero fecal coliform background water, and establishes buffers around marinas based on the dilution volume required to reach the 70 total coliform per 100 ml standard. The dilution formula includes Delaware-specific loading factors, and is as follows:

\[
2 \cdot 10^5 \text{fc} \times 3.3 \text{people/boat} \times 0.065 \text{discharge rate} \times \frac{70 \text{total coliforms per 100 ml}}{\text{average depth}}
\]

In addition, the Shellfish Program also tracks naturally occurring toxic phytoplankton. While the presence of these causative organisms is documented for the Chesapeake Basin, none have occurred at toxic levels.

All data from four stations in the Nanticoke Watershed are in excess of the 70 total coliform/100 ml shellfish harvest standard. Wading sample data collected from one station in the Trap Pond swimming area have led to swimming advisories for an average of 20 days per year. The geometric-mean swimming advisory criterion is 155 total enterococcus colony-forming units/100 ml. The single-sample standard is 360 units/100 ml.

Sampling for total coliform (a bacterial indicator of potential human illness/pathogens) commenced in March, 1991, in response to the illicit harvesting of freshwater clams (Rangia cuneata). Since then, none of the samples collected from Chesapeake Basin waterways have met the internationally mandated standard of 70 total coliform bacteria per 100 ml (running geometric mean), while more than 10 percent of the samples exceeded 330 total coliform per 100 ml. No sources have been directly linked to observable high bacteria counts. However, probable sources of contamination include combined sewer overflows, sewage treatment plants, suburban/urban runoff, agricultural runoff, and runoff from forested land. There is a statistical association between human illness and enteric indicator bacteria levels in ambient water. However, these bacteria are not specific to humans and may be associated with numerous warm-blooded animals. In addition, studies indicate that the bacteria are ubiquitous, possibly surviving in the environment, for example, in leaf litter. Additional studies provide supportive evidence that shows little or no association between indicator bacteria levels and human illness in areas not impacted by human sources or concentrations of domestic animals. As such, baseline data need to be established for bacteria (for example in forest or crop field situations). Bacteria levels in excess of background and associated with human or domestic animal sources — either by direct observation or DNA testing — is the basis for establishing TMDLs for bacteria. However, more studies are needed under extremely controlled conditions. In the absence of DNA testing, shoreline
surveys such as sanitary assessments of pollution sources are used to identify the above sources. A comprehensive strategy should address all sources.

2.3.2.5 Inventory of Potential Sources

Source Type: Agriculture

According to the 1998 Delaware Agricultural Statistics Summary, Delaware has 2,700 farms comprising 580,000 acres. The Chesapeake Basin is comprised of 488,792 total acres, with roughly half of this acreage used for agriculture. Agriculture is Delaware’s number one industry, with poultry the primary agricultural product and largest animal-based industry in the state.

Sussex County is the number-one broiler-producing county in the nation, with over 262 million broilers/roasters grown in 1995 (Delmarva Poultry Industry, Inc., 1996). Within Sussex County, the Indian River, Nanticoke River, and Broad Creek watersheds are meccas of poultry production (McDermott, 1995). For the Chesapeake Basin as a whole, a poultry inventory completed in 1997 indicates that there are 74 poultry farms in the Kent and Sussex County portions of the Basin.

The dairy industry is the second largest animal-based waste generator in Delaware (Goggin et al., 1997). Delaware Department of Agriculture records indicated approximately 100 registered dairy farms in Delaware. The animal inventory for 1987 lists 24 dairy operations in the Sussex and Kent County portions of the Basin. Overall, dairy farms are not increasing in number, although production reports indicate steady increases in total milk production by farm, as well as milk produced per cow.

Delaware’s swine industry is currently undergoing major change. Delmarva is experiencing the arrival of integrated swine operations, similar to those seen in the poultry industry, and overtures have been made to establish contract-growing systems in Delaware. While production numbers may decrease in Delaware, Delmarva may actually experience a net gain in the number of sows located in the region as the larger farms become more prevalent. Operating conditions in Delaware vary widely, with some hogs raised on dirt lots, and others raised in total confinement (Goggin et al., 1997). Based on a 1987 animal inventory, 29 swine farms operate in the Sussex and Kent County portions of the Chesapeake Basin.

Environmental impact of dairy, swine, and beef manure may be of concern on a site-specific basis, but is of relatively less concern than the impact from poultry (McDermott, 1995). Dairy operations exist throughout the state. Beef cattle operations exist throughout the state, but the number of operations increase as one heads south. The swine industry is mostly in Sussex County, aggravating the existing problem of excessive nutrients in the county. The Broad Creek watershed has a high concentration of both swine and poultry operations (McDermott, 1995). A road survey of dairy, poultry, beef, and swine operations (see Map 2.3-1 Known and Potential Nutrient Sources) was accomplished in 1997 for Sussex County. Poultry operations, only, were inventoried for Kent County using 1992 aerial photography. Progress is now under way to complete a comprehensive road survey (inventory) of all animal operations in Kent and Sussex counties and will include the number of animals for future usage.

Water-quality sampling and research from demonstration projects throughout Delaware indicate a strong need to be concerned about the fate and impact of nitrogen, phosphorus, and bacteria on surface and ground waters. According to the Delaware Guidelines for Animal Agriculture (1997), manure can be a valuable agricultural by-product if managed properly. Manure contains three major plant nutrients — nitrogen, phosphorus, and potassium, as well as essential elements like calcium, sulfur, boron, magnesium, manganese, copper, and zinc. Applying manure to fields provides valuable plant nutrients, improves soil tilth, aeration, and water-holding capacity, decreases soil erosion potential, and promotes the growth of beneficial soil organisms. Many manure application systems fail to fully utilize these nutrients. For example, applying manure in excess, or at the wrong time, or improperly handling it, may release nutrients into the air or water. Instead of only nourishing crops, the nutrients become pollutants. The major concern is that excess nitrogen may leach through the soil and into the ground water. Accordingly, nutrient management in areas dominated by animal-based agriculture is a major nonpoint source pollution issue. The Nonpoint Source Program Assessment Report (1995) calculated a statewide nutrient budget (Table 2.3-1) showing nutrient excess of 15,288 tons of nitrogen/year and 10,079 tons of phosphorus/year. According to McDermott (1995), chemical fertilizers alone are applied at rates greater than the calculated crop acreage requirements. When combined with chemical excesses, organic fertilizers, especially manures, become part of the overall problem. McDermott (1995) suggests that chemical fertilizers are less of a concern than manures because the former are more evenly distributed throughout the state. Manures, on the other hand, are not evenly distributed. Manure does not lend itself to inexpensive, easy transport due to its bulk, and thus has a tendency to be land applied in close proximity to the animal operation. The animal production industry, in particular the poultry industry, is not spread out, but rather, is concentrated in specific areas. Transport of manures away from these areas is limited and cost-prohibitive if transport distance is greater than 15 miles (McDermott, 1995).

Another management conflict arises when considering the N and P ratio in poultry manure. Applying poultry
manure at rates that meet crop nitrogen requirements results in over-application of phosphorus. Land application of animal waste can add more P to soils than is removed in harvested crops, resulting in a long-term accumulation of soil P (Sims, 1997). Phosphorus buildup in Delaware soils has been documented by the University of Delaware’s Soil Testing Laboratory (Cooperative Bulletin No. 45, 1993). A summary of 37 years of soil data at the laboratory shows that soil phosphorus levels have been steadily increasing in many areas. In 1994, 72 percent of all commercial crop soil samples received had a “high” or “excessive” level of plant-available phosphorus (no phosphorus fertilizer recommended). Twenty percent of all commercial crop soil samples from Sussex County had double the optimal level of phosphorus. Previous research in other Mid-Atlantic states indicates that it can take from 10 to 20 years, with no additional application of P, for normal cropping practices to deplete soil P from excessive to optimum levels (McCollum, 1991).

The University of Delaware does not recommend P application for fields that have high or excessive levels of plant-available phosphorus. At most, a minor starter application of P in the spring is recommended because soils do not release phosphorus fast enough for seedlings in the spring (McDermott, 1995). In addition, Sims (1995) notes that roughly half of the 290,000 acres of non-pasture cropland in Sussex County is in soybeans. Soybean production requires no nitrogen fertilizer and often only starter amounts of phosphorus. Sims (1995) suggests that, provided manure is not applied to soybean fields, poultry manure alone could meet all crop nutrient needs in Sussex County. McDermott (1995) suggests that any solution to phosphorus surface-water contamination must reconcile excessive phosphorus delivery with farmers’ concerns for adequate crop fertilization.

In 1993, the Nonpoint Source Program, in conjunction with the Sussex Conservation District, initiated an intensive Watershed Implementation Project for the Nanticoke Watershed. The main goal of the project is to complete comprehensive resource conservation plans and provide follow-up on farms in the Broad Creek subwatershed. In 1994, a surface-water monitoring program was initiated to evaluate the effect of Best Management Practices (BMPs) on water quality. All surface-water monitoring samples were analyzed for ammonia, nitrates, kjeldahl nitrogen, ortho phosphorus, and total phosphorus. Grab samples were collected at all sites twice a month from July 1994 to September 1997. Results of this monitoring are available through the Nonpoint Source Program. In addition, Table 2.3–2 summarizes other conservation planning initiatives that have taken place in the entire Chesapeake Basin since 1985.

The Nanticoke River Watershed is also a high-priority area for determining TMDLs for nutrients. In order to develop TMDLs, the Nonpoint Source Program funded development of a nitrogen and phosphorus budget for all major subwatersheds in the Nanticoke Watershed. The subwatersheds of the Nanticoke for which nutrient budgets were developed include Broad Creek, Deep Creek, Marshyhope River, Gum Branch, Nanticoke River, and Gravelly Branch.

Nutrient loads were calculated for different land uses, point sources, and nonpoint sources. Nonpoint source nutrient loads were calculated for wet, normal, and dry years. Point source loads were obtained from flow data and chemical analysis data obtained from the Department. In all six subwatersheds, the major source of nitrogen was cropland, which contributed N ranging from 45 to 79 percent of the total N (Ritter, 1995). The only significant point source for N is the DuPont nylon plant in Seaford (Nanticoke River subwatershed). In the Nanticoke River subwatershed, for a normal year, 45 percent of the N load is from cropland, and 39 percent from point sources. The Nanticoke River subwatershed is the only watershed that has a significant N point source load. In the other subwatersheds, the only significant point source for N is the Laurel sewage treatment plant in the Broad Creek subwatershed.

According to Ritter (1995), nitrogen from septic tanks ranges from 3 percent in three of the subwatersheds to 6 percent in Gravelly Creek. After cropland, forestland is the next largest contributor to nonpoint source nitrogen load. Nitrogen loads from forestland ranged from 6 percent for Nanticoke River to 30 percent for Gravelly Creek. Phosphorus load contributions for forestland ranged from 8 percent for Nanticoke River to 36 percent for Gravelly Creek.

Table 2.3–1

<table>
<thead>
<tr>
<th>NUTRIENT CONTRIBUTION BY SOURCE</th>
<th>TONS NITROGEN/YR (% OF TOTAL)</th>
<th>TONS PHOSPHORUS/YR (% OF TOTAL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Fertilizer</td>
<td>22,127 (66%)</td>
<td>7,858 (59%)</td>
</tr>
<tr>
<td>Poultry</td>
<td>8,651 (25%)</td>
<td>3,845 (29%)</td>
</tr>
<tr>
<td>Cattle</td>
<td>2,175 (7%)</td>
<td>1,215 (9%)</td>
</tr>
<tr>
<td>Swine</td>
<td>365 (1%)</td>
<td>285 (2%)</td>
</tr>
<tr>
<td>Sludge</td>
<td>183 (.5%)</td>
<td>110 (1%)</td>
</tr>
<tr>
<td>Wastewater</td>
<td>3 (--)</td>
<td>&lt; .1 (--)</td>
</tr>
<tr>
<td><strong>Total Nutrient</strong></td>
<td><strong>33,504</strong></td>
<td><strong>13,313</strong></td>
</tr>
<tr>
<td>Nutrients Required</td>
<td>18,216</td>
<td>3,234</td>
</tr>
<tr>
<td><strong>Nutrient Excess</strong></td>
<td><strong>15,288</strong></td>
<td><strong>10,079</strong></td>
</tr>
</tbody>
</table>

The Broad Creek subwatershed has the greatest density of poultry per acre than any other subwatershed in the state. Approximately 50 percent of the land use is cropland while 44 percent is classified as forestland. Broad Creek and Nanticoke River have the largest number of poultry houses. These two subwatersheds also have the largest area of cropland. There are approximately 500 poultry and swine operations in the Broad Creek subwatershed. Assuming 450 poultry growers in this sub-watershed raise 40,000 birds/flock with 5.75 flocks per year, the total manure production for the watershed would be over 100,000 tons/yr. Based upon the nitrogen content of broiler manure reported by Malone et al. (1992), the nitrogen application rate to cropland would be 175 lb/ac/yr. At these potential application rates, manure becomes a serious disposal problem that can create surface and ground-water quality problems. Both Broad Creek and Nanticoke River subwatersheds have a surplus of manure that ideally should be transported to other parts of the watershed for land application. The Nanticoke River and Broad Creek are both rated very high in susceptibility to nonpoint source water pollution and are two of the highest priority watersheds in Sussex County (1995 Nonpoint Source Assessment Report).

According to Ritter (1995), cropland is the largest source of phosphorus in all six subwatersheds. Phosphorus loads from cropland ranged from 50 percent in the Nanticoke River subwatershed to 78 percent in the Marshyhope Creek subwatershed. The only significant source of point source phosphorus loads occurred in the Nanticoke River subwatershed. Approximately 35 percent of the phosphorus load originated from point sources, with the DuPont nylon plant being the largest contributor. Phosphorus loads from forestland varied from 8 percent in the Nanticoke River subwatershed to 36 percent in the Gravelly Creek subwatershed. Septic tanks contributed < 4 percent of the phosphorus load in all six subwatersheds. Ritter (1995) suggests significant reductions in nitrogen and phosphorus loads could be achieved in the Nanticoke River subwatershed by reducing the nutrients in the point source loads.

On a final note, the rate of loss of farms and acreage in farms in Delaware has slowed in the last decade (Delaware Agricultural Statistics, 1996). Still, Delaware converts on the average a little over one percent of its farmland to other uses each year. While the beef cattle, dairy, and swine industries are not growing significantly, the poultry

### Table 2.3-2

**CHESAPEAKE BAY DRAINAGE AREA CONSERVATION ACTIVITIES**

<table>
<thead>
<tr>
<th>PRACTICE</th>
<th>CODE</th>
<th>UNIT</th>
<th>PLANNED NOT APPLIED</th>
<th>APPLIED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Management System</td>
<td>312</td>
<td>Number</td>
<td>187</td>
<td>244</td>
</tr>
<tr>
<td>Waste Storage Facility</td>
<td>313</td>
<td>Number</td>
<td>126</td>
<td>244</td>
</tr>
<tr>
<td>Composter</td>
<td>317</td>
<td>Number</td>
<td>64</td>
<td>193</td>
</tr>
<tr>
<td>Nutrient Management</td>
<td>590</td>
<td>Acres</td>
<td>33,429</td>
<td>40,717</td>
</tr>
<tr>
<td>Pest Management</td>
<td>595</td>
<td>Acres</td>
<td>32,777</td>
<td>40,065</td>
</tr>
<tr>
<td>Filter Strip</td>
<td>393</td>
<td>Acres</td>
<td>288</td>
<td>30</td>
</tr>
<tr>
<td>Cover Crop</td>
<td>340</td>
<td>Acres</td>
<td>7,401</td>
<td>2,513</td>
</tr>
<tr>
<td>Residue Management</td>
<td>344</td>
<td>Acres</td>
<td>27,226</td>
<td>15,971</td>
</tr>
<tr>
<td>Grassed Waterway</td>
<td>412</td>
<td>Acres</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Conservation Plans (Systems)</td>
<td>108</td>
<td>Acres</td>
<td>106,657</td>
<td>30,072</td>
</tr>
<tr>
<td>Soil Erosion Reduced</td>
<td>–</td>
<td>Tons/Ac/Year</td>
<td>–</td>
<td>43,612</td>
</tr>
</tbody>
</table>

Notes:
1. Information reflects only that data entered into the NRCS FOCS system. Other practices installed without NRCS or Conservation District Assistance are not included.
2. Resource Concern Data other than Soil Erosion Reduced not included.
3. FSA records indicate $2,224,800 spent on conservation through ACP Program from 1980 – 1996. Pro-rated for Chesapeake Bay Watershed — $735,000.
4. Program started in FY 97 (for five-year period) targets up to $2.6 million dollars in cost share in the Upper Nanticoke Watershed.
industry continues to increase its production (McDermott, 1995). This continued growth will require cropland for nutrient utilization. However, alternative markets for poultry litter (such as the horticulture industry or an energy source) must also be considered. On the peninsula, the poultry industry has developed the infrastructure necessary to perpetuate itself and grow. Here, the farmers grow the feed, poultry producers raise the birds, and the poultry integrator companies process them. Waste management and alternative uses for poultry litter must grow with the industry as well (McDermott, 1995).

Specific implementation/management recommendations that address agriculture as a contaminant source can be found in Section 3.1. For more information on nutrients and agricultural impacts, contact the Nonpoint Source Program.

**Source Type: Pesticide and Fertilizer Mixing, Loading, and Storage Areas**

These sites serve as areas to store, mix, and load pesticide products and/or liquid and solid fertilizer products. Products are generally stored in large bulk quantities. Products may be stored in individual packages in a warehouse or in large mixing tanks, drums, or mini-bulk containers.

The potential exists for a product to be released during mixing or loading of the product onto transporter vehicles or application equipment. The potential also exists for storage container failure. While some sites have modern containment systems, including dikes, berms, and product recovery systems, many do not.

Currently, the design of these facilities is not regulated, and no monitoring data exist for these sites. However, the U.S. EPA is developing draft regulations that address this shortcoming. Refer to *Map 2.3-1 Known and Potential Nutrient Sources* for the location of known sites. For more information, contact the Delaware Department of Agriculture, Pesticides Section.

**Source Type: On-Site Septic Systems**

Septic systems are the main method for treatment of domestic wastewater used in the rural or unsewered areas of the Chesapeake Basin. In portions of unsewered sections, especially rural homesteads and older subdivisions, cesspools are still being used. Most are undocumented. A cesspool is usually a large, open-bottomed tank, which drains both liquid and solid wastes directly underground. A septic system is a more engineered waste disposal system compared to a cesspool, and is usually comprised of a septic tank for solids and a distribution box and drainage field for liquids. The drainage field may be either gravity-fed or pressure-dosed.

Although domestic wastewater can contain a wide range of substances, its chemical composition is relatively simple compared to municipal wastewaters, which obtain liquid wastes from a variety of sources including housing, commercial, and industrial activities. Potential contaminants in domestic wastewater include dissolved organic matter, heavy metals, biological oxygen demand (BOD), pathogenic microorganisms, and soil nutrients such as nitrogen and phosphorus.

New Castle, Kent, and Sussex counties, and municipalities have governing authority over sewered areas and their locations. Currently, none of the counties has a central sewer district within the Basin. However, the municipalities of Georgetown, Greenwood, Bridgeville, Seaford, and Laurel have jurisdiction over sewer systems and sewer districts.

The 1990 census of population and housing provides percentages of central sewer systems vs. on-site septic systems. In the Chesapeake Basin, 82.4 percent of households had on-site septic systems, while 17.6 percent were centrally sewered. By comparison, statewide, 65 percent of households had central sewer, and 35 percent had on-site septic systems.

In 1985, the Department conducted site evaluations statewide and ceased usage of the archaic percolation test. Since 1985, a total of 15,500 site evaluations have been conducted in the Chesapeake Basin. This count includes lots evaluated prior to subdividing, possibly suggesting a lower number of sites than that actually permitted. Based upon septic records, 18,000 permits have been issued in the Chesapeake Basin since 1985.

The Chesapeake Basin has one of the highest percentages (95 percent of land area served by septic systems as compared to other basins in the state. Many of the parcels are strip developments along rural roadways. Due to moderate-to-poorly drained soil conditions, moderate limitations for on-site septic disposal exist. Systems that are suitable for this area range from gravity-fed systems to engineered, pressured systems.

Ritter and Scarborough (1995) estimated the nitrogen loading rate from septic disposal systems to ground water within the Nanticoke watershed to be approximately 14.1 to 28.2 pounds per acre per year. This loading rate is considerably higher than the 0.7 pound per acre per year nitrogen load in the Piedmont Basin. The higher rate is due to more permeable sandy soils and higher water table. For nitrogen loads, septic tank N content ranged from 2.9 percent in Marshyhope Creek and Nanticoke Creek to 5.5 percent in Gravelly Creek. Phosphorus loads for septic tanks ranged from <1.0 percent in Marshyhope Creek to 3.5 percent in Deep Creek (Ritter, 1995). These data suggest that septic tanks are not a major contributor to nonpoint source loads of nitrogen and phosphorus. However, this study only evaluated loading rates for functioning systems and did not calculate loads based on a percentage of inoperable or failing septic tanks.
Installing a septic system in Delaware involves three steps. The first step requires a site evaluation. Site evaluations consist of investigating, evaluating, and reporting basic soil and site conditions. Each report describes specific site conditions or limitations including, but not limited to: isolation and separation distances, slopes, existing wells, cuts and fills, and unstable landforms. Each report also contains information about zoning verification; the type of on-site disposal system that must be constructed in the acceptable on-site disposal area; the results of the hydraulic conductivity test conducted; easements; and underground and overhead utilities in the evaluated area. This siting procedure ensures that septic systems are properly located utilizing the following soil properties: permeability, texture, structure, consistency, redoximorphic features, slope, and depth to rock.

The second step requires hiring a licensed system designer to design the septic system required by the approved site evaluation and obtaining design approval by the Ground Water Discharges Section. The final step after the permit is approved involves hiring a licensed system contractor to construct the system under supervision of the section.

In spite of this permitting process, there are approximately 80 septic system complaints filed with the Department on a yearly basis statewide in regards to malfunctioning on-site septic systems. On average, during a given year, the Department issues 2,200 on-site septic permits per year. Approximately 25 percent of these permits are for replacing existing disposal systems or components, with the remaining 75 percent of the septic permits issued for new home construction on individual lots. For further information, contact the Ground Water Discharges Section.

**Source Type: Large On-Site Community Disposal Systems**

Large community septic systems are on-site wastewater disposal systems which serve more than one lot or parcel or more than one dwelling unit of a planned development or industrial use. The projected daily wastewater flow in these types of systems is greater than 2,500 gallons. A large community system is a more complex waste disposal system, usually comprised of holding tanks for solids, and a pressure dosed distribution system. Similar to domestic wastewater from smaller on-site septic systems, community systems contain a wide range of substances: dissolved organic matter, heavy metals, pathogenic microorganisms, and nutrients such as nitrogen and phosphorus.

In the Chesapeake Basin, there are 13 permitted large on-site wastewater treatment and disposal systems. These systems are regulated under The Regulations Governing the Design, Installation, and Operation of On-Site Wastewater Treatment and Disposal Systems. These systems have a projected daily flow of wastewater ranging from 2,500 gpd to 24,300 gpd. All projects with estimated flows exceeding 2,500 gpd must be accompanied by a preliminary ground-water assessment, which is then reviewed by the Department’s Ground Water Protection Branch. Eighty-five percent of the large on-site community systems fall under the state’s criteria for requiring a site to have a licensed operator to maintain the system to ensure proper maintenance and operation. Seventy-seven percent of the large community system owners are required to monitor ground water on the project site for the following parameters: Depth to Water Table, Temperature, pH, Specific Conductance, Total Nitrogen, Ammonia as Nitrogen, Nitrate (NO₃) as Nitrogen, Coliform Bacteria (Total & Fecal), and Total Dissolved Solids. These monitoring parameters enable the Department to detect contaminants entering the ground water from on-site disposal systems. Such monitoring also helps the Department to discover/prevent ground-water contamination from crossing the property boundary of the site.

**Source Type: Land Application of Wastes**

Land application of wastewater, biosolids, and other residual wastes in a soil system is a viable alternative for the treatment, disposal, and beneficial reuse of municipal and some industrial wastes. Land treatment of wastewater and other wastes provides one of the most environmentally sound methods of managing wastewater and other residuals. The constituents (nutrients) in the wastewater are taken up by selected plants (farming), fixed in soluble forms (metal, phosphorus) in the soil, evolve as gases (ammonia), or leach into the ground water (nitrate and nitrite) where they are diluted. Land application of wastewater and other wastes provides ground-water recharge and enables governmental agencies the power to create incentives to maintain farmland or green spaces. The basic criteria for land treatment are:

- Quality standards for ground water and surface waters are not exceeded;
- Land application of wastes does not present a significant health problem; and
- The soil is not degraded so as to prevent future use for agriculture, forestry, or other planned development.

Current land treatment facilities are designed for a 25- to 50-year site life based on wastewater flow, nutrient loading, and metal loading. During the operation of systems, nutrient and metal content of the wastewater is monitored yearly to track the actual site life of these facilities over the long term. Generally, long-term effects of land treatment have shown decreased nutrient loading (compared with conventional farming fertilization practices); nutrient (nitrate) reduction in ground-water recharge; stream discharge decreases due to required conservation planning; and agricultural lands preservation.

In the Chesapeake Basin, there are six spray-irrigation land treatment facilities (see Map 2.3-1 Known and
Potential Nutrient Sources), ranging from food processing and textile finishing to domestic wastewater treatment and disposal. These systems have a projected daily flow of wastewater ranging from 3,200 to 452,000 gpd. All permitted land treatment systems undergo a comprehensive design review process. The review covers soil and hydrologic investigative work, and treatment and waste-loading calculations. After the permit review process is completed, land treatment systems are constructed based on plans and specifications submitted to the Department, and done so under the supervision of licensed operators. These licensed operators, in turn, properly operate and maintain the systems.

Two of the six permitted spray irrigation facilities in the Chesapeake Basin have recently ceased operations. The other four facilities continue to monitor the ground water for the following parameters: depth to water table, temperature, pH, specific conductance, total nitrogen, ammonia as nitrogen, nitrate as nitrogen, phosphorus, sodium, chloride, total dissolved solids, and coliform bacteria (domestic waste facilities only). These monitoring requirements enable the Department to detect contaminants entering the ground water from the land treatment systems. This will also help the Department prevent ground-water contamination from crossing adjacent property boundaries of the site. There are no permitted biosolid land application sites in the Chesapeake Basin. For further information, contact the Ground-Water Discharges Section.

Source Type: National Pollutant Discharge Elimination (NPDES) Reporting Facilities

Municipal and industrial sites that discharge wastewater to surface waters are subject to limitations, monitoring requirements, and other terms and conditions identified in the individual NPDES permit issued to each site. Individual permittees must report monitoring results monthly, using the Discharge Monitoring Report (DMR) form developed specifically for each facility. The DMR lists parameters in the discharge that have a reasonable potential to cause or contribute to water-quality problems in receiving waters. Example parameters are temperature, dissolved oxygen, pH, copper, oil and grease, benzene, and PCBs. Although the DMRs are submitted monthly, actual monitoring frequency ranges from “continuously” to “once per year,” depending on the discharge’s characteristics and its volume relative to the receiving waters.

Industrial sites that discharge only storm water may be permitted under an NPDES General Permit, which is a single permit that applies to a group of similar dischargers, e.g., trucking operations. Monitoring for storm-water discharges is typically less frequent, for example, three times in five years. Table 2.3-3 lists the point source discharges for the Nanticoke Watershed.

Source Type: Landfills

Decomposition of organic waste such as household garbage or food processing by-products disposed of in landfills and dumps can be a source of unwanted nutrients to ground water and surface water. The decomposition process in landfills produces soluble nitrogen-rich decay products such as ammonia, nitrate, and complex organic compounds. Rainwater seeping through the waste transports these soluble nitrogen-rich compounds into ground water that ultimately discharges into streams. To produce significant quantities of nutrients, a landfill must contain large quantities of organic waste.

To be considered a potential nutrient source for the purposes of this assessment, a landfill or dump has to be at least 5 acres in size and contain household garbage or food processing by-products. Six landfills in the Chesapeake Basin meet these criteria facilities (see Map 2.3-1 Known and Potential Nutrient Sources). Two are operating municipal solid waste landfills owned by the Delaware Solid Waste Authority. These landfills receive all municipal waste generated in Kent and Sussex counties, and are regulated by the Department’s Solid Waste Management Branch. The other four sites are closed landfills under the jurisdiction of the Site Investigation and Restoration Branch of the Department. Routine ground-water and surface-water monitoring of these sites indicates there have been no significant nutrient releases to date. For more information about these landfills contact the Solid Waste Management Branch or the Site Investigation and Restoration Branch.

Source Type: Toxics Release Inventory (TRI) Facilities

Manufacturing facilities report annually under the Toxics Release Inventory (TRI) on any reportable toxic chemical that is manufactured, processed, or otherwise used above certain thresholds. The reportable list includes 576 individual chemicals and 28 chemical categories. Reports contain data on releases of the specific chemical to air, water, and land, as well as information on chemicals in waste transported off-site or managed on-site.

There are 14 facilities within the Basin that have reported under TRI since reporting began in 1988 (refer to Table 2.3-4 and Map 2.3-1 Known and Potential Nutrient Sources). For the most recent reporting year (1998), 12 facilities within the Basin (all located within the Nanticoke watershed) submitted 49 reports for 32 different chemicals. All reported on-site releases, for 1998, were to the air except for the release by DuPont Seaford of nitrates to the Nanticoke River.

For more information about the TRI database, contact the Emergency Planning and Community Right-to-Know (EPCRA) Reporting Program.
Combined sewers are designed to carry both sanitary sewage (wastewater from domestic, commercial, or industrial sources) and urban storm-water runoff and to convey the "combined" sewage and storm-water flow to the treatment facility. Combined sewer overflows occur during wet weather events when the combined sewerage and storm-water flows exceed the hydraulic capacity of the sewer system. CSOs are designed to relieve the sewer system of the excess flow and discharge it directly to a tributary or stream channel.

### 2.3.3 CHEMICALS

#### 2.3.3.1 Category Definition and Characteristics

Contaminant sources located within the Delaware portion of the Chesapeake Basin consist of a variety of chemical contaminants, including heavy metals, solvents and organics, polychlorinated biphenyls (PCBs), pesticides and herbicides, and petroleum. Chemical contamination may adversely impact human health or the environment through various toxic effects that different chemicals pose.

Chemical contaminants have been grouped into the following classes:

- **Heavy Metals** — Includes iron, arsenic, cadmium, chromium, manganese, nickel, lead, barium, and zinc. Some metals are carcinogenic or poisonous to humans and/or other organisms. In high concentrations, metals such as iron or manganese can render water unsuitable for drinking due to taste and staining, even though they might not cause specific health problems.

- **Solvents and Other Organic Compounds** — Includes organic chemicals such as chlorinated solvents, degreasers, paint thinners, alcohols, and certain chemical feedstocks. Many of these chemicals are carcinogenic or poisonous to humans and/or other organisms.

- **PCBs** — A class of organic compounds formerly used in electrical transformers and switches. These compounds are generally insoluble in water and break down very slowly under normal environmental conditions. They can accumulate in stream sediments where they can be directly or indirectly ingested by fish. Most forms of PCBs are considered carcinogenic.

- **Pesticides and Herbicides** — Are carcinogenic and/or poisonous to humans and other organisms. Many pesticides or herbicides have the potential of being biologically concentrated in the highest part of the food chain.

- **Petroleum** — Includes but is not limited to gasoline, heating oil, diesel fuel, kerosene, and waste oil. Certain compounds contained within each product, such as benzene, are carcinogenic or poisonous to humans and/or other organisms.

- **Other Inorganic Compounds** — Includes chemicals such as chlorides, sulfates, and Total Dissolved Solids (TDS).

Contaminant sources located within the Chesapeake Basin containing the above chemical groups are discussed in more detail under the different source types discussed below. Source locations are provided on Map 2.3-2 Known and Potential Chemical Sources, with Map 2.3-3 Known and Potential Chemical Sources – City Details showing close-ups for the cities and towns in the Basin.

#### 2.3.3.2 Inventory of Potential Sources

**Source Type: Agriculture**

In addition to the nonpoint source nutrients discussed above, many agricultural practices also apply non-nutrient chemicals, such as lime or pesticides, to large areas of land in the Basin. If care is not taken, this can be a significant source of chemical contamination.

**Source Type: Pesticide and Fertilizer Mixing, Loading, and Storage Areas**

These sites store, mix, and load pesticide products and liquid and solid fertilizers. The products are usually purchased in large bulk quantities, and stored in individual packages in a warehouse, or in large mixing tanks, drums, or mini-bulk containers.

Product may potentially be released during mixing or loading into transporter or application equipment. The

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**Table 2.3-3**

POINT SOURCE DISCHARGES FOR THE NANTICOKE WATERSHED

*Individual NPDES Permittees in the Chesapeake Basin*

<table>
<thead>
<tr>
<th>PERMIT NO.</th>
<th>FACILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE 0020249</td>
<td>Bridgeville WWTF</td>
</tr>
<tr>
<td>DE 0000035</td>
<td>DuPont Seaford</td>
</tr>
<tr>
<td>DE 0020125</td>
<td>Laurel WWTF</td>
</tr>
<tr>
<td>DE 0050725</td>
<td>Mobile Gardens Trailer Park</td>
</tr>
<tr>
<td>DE 0020265</td>
<td>Seaford WWTF</td>
</tr>
<tr>
<td>DE 0050971</td>
<td>S. C. Johnson and Son, Inc.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MAJOR OR MINOR?</th>
<th>INDUSTRIAL OR MUNICIPAL?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
<td>Mun.</td>
</tr>
<tr>
<td>Major</td>
<td>Ind.</td>
</tr>
<tr>
<td>Minor</td>
<td>Mun.</td>
</tr>
<tr>
<td>Minor</td>
<td>Mun.</td>
</tr>
<tr>
<td>Major</td>
<td>Mun.</td>
</tr>
<tr>
<td>Minor</td>
<td>Ind.</td>
</tr>
</tbody>
</table>
product storage containers may also fail. While some sites have modern containment systems, including dikes, berms, and product recovery systems, others do not.

Currently, the design of such facilities is not regulated. Consequently, no data are available on pesticide/fertilizer releases from mixing, loading, or storage areas.

**Source Type: Landfills**

Waste disposed of in landfills and dumps can be a source of a wide variety of contaminants. Rainwater seeping through a landfill dissolves or leaches out contaminants present in the waste. The resulting leachate, if not properly managed and contained, may contaminate nearby ground water and surface water. The composition and concentration of the leachate depends on the type and volume of waste in the landfill. Landfills and dumps in the Chesapeake Basin primarily contain:

- Municipal waste — trash from households, offices, and stores with significant amounts of putrescible food waste;
- Miscellaneous non-putrescible waste — waste from road clean-up activities, construction and demolition activities, old appliances, etc.; and/or
- Coal ash — from combustion of coal to generate electric power and steam.

**Table 2.3-4**

<table>
<thead>
<tr>
<th>FACILITY NAME</th>
<th>YEARS</th>
<th>CHEMICALS REPORTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allen Petroleum</td>
<td>1998</td>
<td>Benzene, Ethylbenzene, N-Hexane, MTBE, Toluene, 1,2,4-Trimethylbenzene, Xylene, Zinc Compounds</td>
</tr>
<tr>
<td>American Original Foods</td>
<td>1987 – 1989</td>
<td>Phosphoric Acid, Sodium Hydroxide</td>
</tr>
<tr>
<td>Agrink Foods</td>
<td>1989 – 1998</td>
<td>Ammonia, Chlorine</td>
</tr>
<tr>
<td>Lebanon Chemical</td>
<td>1989 – 1990</td>
<td>Manganese Compounds, Phosphoric Acid</td>
</tr>
<tr>
<td>Nanticoke Homes</td>
<td>1991 – 1998</td>
<td>Dichloromethane, Ethylene Glycol, Methylene bis(phenylisocyanate), Toluene, Xylene</td>
</tr>
<tr>
<td>Peninsula Oil – Blades</td>
<td>1998</td>
<td>Benzene, Ethylbenzene, N-Hexane, MTBE, Toluene, 1,2,4-Trimethylbenzene, Xylene</td>
</tr>
<tr>
<td>Perdue – Bridgeville</td>
<td>1988 – 1998</td>
<td>Copper Compounds, Manganese Compounds, Zinc Compounds</td>
</tr>
<tr>
<td>Rite Off</td>
<td>1993 – 1998</td>
<td>1,1-Dichloro-1-fluoroethane, Dichloromethane, Glycol Ethers, N-Hexane, Tetrachloroethylene, 1,1,1-Trichloroethane, Trichloroethylene</td>
</tr>
</tbody>
</table>
Leachate from municipal waste landfills is typically high in complex organic degradation compounds, ammonia, chlorides, alkalinities, chemical and biological oxygen demand (COD and BOD), iron, and sulfate. It may also have smaller amounts of volatile organic compounds and heavy metals. Besides leachate, municipal waste landfills also generate large amounts of methane gas.

Leachate from miscellaneous non-putrescible waste landfills is typically high in alkalinity, iron, and sulfate, but lacks the organic decay products and ammonia typical of municipal waste leachates. It may also contain smaller amounts of volatile organic compounds and heavy metals. Miscellaneous non-putrescible waste landfills can generate methane gas if they contain wood waste and hydrogen sulfide gas if they contain gypsum wallboard.

Leachate from coal-ash landfills is typically high in sulfate and iron and often contains a variety of heavy metals, including arsenic. These landfills do not generate gases.

Excluding the landfills covered under the Site Investigation and Restoration Branch (SIRB), there are nine landfills and dumps documented in the Chesapeake Basin (Map 2.3-2 Known and Potential Chemical Sources). Two of these landfills are major municipal waste landfills operated by the Delaware Solid Waste Authority. These two landfills, each covering 60 to 70 acres, receive all municipal waste generated in Kent and Sussex counties. Liners to protect ground water and surface water from contamination underlie each landfill. They also include leachate and methane collection systems. Monitoring results from these two landfills indicate that they are significantly impacting the environment.

There are five miscellaneous non-putrescible waste landfills and dumps in the Chesapeake Basin. All are less than 6 acres in size, and the waste is generally only a few feet thick. None of these landfills is operating today.

There is one coal-ash landfill and one coal-ash settling pond complex in the Chesapeake Basin. Both are located at the DuPont Seaford plant. Monitoring results indicate that these coal-ash areas may be causing sulfate and arsenic contamination of local ground water. This site is currently under investigation.

For more information about these landfills, contact the Solid Waste Management Branch.

**Source Type: Tire Piles**

There are five large waste tire piles in the Chesapeake Basin. The piles contain 3,000 to 50,000 tires (see Map 2.3-2 Known and Potential Chemical Sources). Other than serving as a breeding ground for mosquitoes, these tire piles are causing no apparent environmental problems. However, these piles do present a significant environmental risk if they catch on fire. Tire pile fires are very difficult to put out. Large tire piles may burn for weeks before being extinguished. Tire pile fires generate large amounts of noxious smoke that may necessitate evacuation of downwind residents. The fires also generate organic liquids that can contaminate ground water and surface water.

For more information about these tire piles, contact the Solid Waste Management Branch.

**Source Type: Hazardous Waste Facilities**

The Hazardous Waste Management Branch regulates facilities that generate, accumulate, transport, treat, store, or dispose of hazardous waste. Many manufacturing processes commonly generate hazardous waste. If released, hazardous waste can cause notable harm to human health and the environment. Hazardous waste can be of two types:

- Listed hazardous waste. Listed hazardous wastes are specifically identified in the Delaware Regulations Governing Hazardous Waste. Currently, there are more than 400 such wastes listed. The wastes are listed as hazardous because they are known to be harmful to human health and the environment.
- Characteristic hazardous waste. Even if a waste is not listed, it may still be regulated as hazardous if a characteristic of hazardous waste is exhibited. Characteristics of a hazardous waste include ignitability, corrosivity, reactivity, and toxicity.

Within the Chesapeake Basin, 83 facilities are identified as hazardous waste generators. Of the 83, ten facilities have been identified as large quantity generators (LGQ), generating greater than 2,200 pounds of hazardous waste per month. Twenty-nine facilities have been identified as small-quantity generators (SQG), generating between 220 pounds and 2,200 pounds of hazardous waste per month. Forty-four facilities have been identified as conditionally exempt small-quantity generators (CESQG), generating less than 220 pounds per month. The Site Index Database contains a list of these sites, along with the types of hazardous waste generated at each site.

Although all facilities regulated by the Hazardous Waste Management Branch have the potential to release contaminants to the environment, most facilities manage their wastes in a responsible manner and, thereby, minimize the possibility of a release occurring. Furthermore, the proactive regulatory stance adopted by the Hazardous Waste Management Branch has increased companies' awareness and usage of proper hazardous waste management practices. For further information about hazardous waste generators in the Chesapeake Basin, please contact the Hazardous Waste Management Branch.

**Source Type: Hazardous Chemical Inventory Reporting Facilities**

Facilities report under the Hazardous Chemical Inventory for each hazardous chemical (as defined by OSHA) or extremely hazardous substance (EHS) present above
threshold quantities. The basic threshold is 55 gallons or 500 pounds, whichever is lower, based on the maximum amount present on site at any time during the calendar year. Certain EHSs have a lower threshold. For each chemical or mixture, facilities report the identity of the substance, the amount present, and storage location information. This information has three primary purposes. Local Emergency Planning Committees (LEPCs) use it to develop plans to prepare for and respond to chemical emergencies in their districts. The 911 Fire Dispatch centers access the chemical information during emergencies at facilities and provide this information to local fire fighters and other emergency personnel responding to the site. The information is also available to the public to promote public participation in managing chemical risks in the community.

Approximately 1,200 facilities statewide report chemicals each year to the Hazardous Chemical Inventory, with an estimated 300 of these facilities located in the Chesapeake Basin. The data are made available to users through the Computer-Aided Management of Emergency Operations, or CAMEO, data system. The CAMEO system contains basic facility information such as facility name and street address, as well as the chemical-specific inventory information. CAMEO also contains a variety of other data modules used for emergency planning and response.

CAMEO runs in conjunction with a basic GIS mapping system named MARPLOT. While New Castle County is presently the only county to use MARPLOT, efforts are under way in Sussex County to map reporting facilities. Mapping will be performed by the Sussex County LEPC. Similar mapping for Kent County has yet to be planned. MARPLOT layers should be easily transferred to the Department’s GIS system for inclusion in watershed assessments. While these facilities report only the presence of chemicals and not releases to the environment, a geospatial representation of these facilities would contribute greatly to the Department’s overall knowledge of potential sources of chemical contamination.

Therefore, the Chesapeake Basin Team recommends that the Department encourage and support the efforts of the LEPCs to map the facilities in their districts and to periodically update information. If efforts by the LEPCs do not meet the needs of the Department, the Team recommends that funding be sought to have this mapping performed either by the LEPCs or the Department.

The Hazardous Chemical Inventory reporting and CAMEO data systems are managed by the Emergency Planning and Community Right-to-Know (EPCRA) Reporting Program and can be contacted.

Source Type: Toxics Release Inventory (TRI) Reporting Facilities

Manufacturing facilities report annually under the Toxics Release Inventory (TRI) on any reportable toxic chemical that is manufactured, processed, or otherwise used above certain thresholds. The reportable list includes 576 individual chemicals and 28 chemical categories. Reports contain data on releases of the specific chemical to air, water, and land, as well as information on chemicals in waste transported off-site or managed on-site.

There are 14 facilities within the Basin that have reported under TRI since reporting began in 1988 (refer to Table 2.3-4, Map 2.3-2 Known and Potential Chemical Sources, and Map 2.3-3 Known and Potential Chemical Sources – City Details). For the most recent reporting year (1998), 12 facilities within the Basin (all located within the Nanticoke Watershed) submitted 49 reports for 32 different chemicals. All reported on-site releases, for 1998, were to the air except for the release by DuPont Seaford of nitrates to the Nanticoke River.

For more information about the TRI database, contact the Emergency Planning and Community Right-to-Know (EPCRA) Reporting Program.

Source Type: Superfund Sites

The investigation and remediation of this country’s most serious hazardous waste sites are performed through the Federal Superfund Program, which established a National Priority List (NPL). In 1990, Delaware enacted the Hazardous Substance Cleanup Act (HSCA), administered by the Site Investigation and Restoration Branch (SIRB), to deal with other potentially harmful sites not addressed through the Federal Program. In 1993, the SIRB Branch initiated the Voluntary Cleanup Program (VCP), which is administered under the Hazardous Substance Cleanup Act. The VCP is primarily designed to address the properties that are being evaluated for transaction or redevelopment and properties where no immediate threat to human health or the environment exists.

A total of 34 SIRB sites, either under state or federal jurisdiction, are located in the Chesapeake Basin. The Sussex County Landfill #5 and the Harvey & Knott Drum Site, are on the NPL while the Seaford Arbuthus well is currently under EPA Operation & Maintenance (O&M).

The 37.5-acre Sussex County Landfill #5 operated from 1970 until 1979, and accepted mixed municipal and industrial wastes. After closure, monitoring wells were installed at the site, and a ground-water plume, comprised of organics and select metals, was found extending 400 to 500 yards from the site. Subsequent monitoring has shown that the plume has ceased to increase in size. Ground water on-site is being monitored semi-annually and is being evaluated under the EPA Five-Year Reviews during O&M phase.

The 3-acre Harvey and Knott Drum Site was an operating open dump and burning area between 1963 and 1969.
The facility accepted sanitary, municipal, and industrial wastes, some of which may have comprised of sludges, paints, pigments, and solvents. Volatile organic compounds and metals were detected in ground water at the site. Prior EPA activities at the site included a large-scale drum and soil removal, capping of lead-contaminated soils, and removal and disposal of water contained in a pond located in the drum disposal area. On-site ground water is currently being monitored semi-annually during the EPA O&M Phase. It appears that ground-water contamination is localized, and that any contaminated ground water-to-surface water discharge is being successfully filtered within the adjacent wetlands.

Contamination in the Seaford Arbutus well was initially discovered through odor complaints from residents. An ensuing Site Inspection discovered high concentrations of tetrachloroethylene (PCE) and lesser concentrations of trichloroethylene (TCE) in the ground water. The EPA Removal Branch issued an Administrative Order for Removal Response Action to the responsible parties. Currently, a granular activated-carbon absorption system is in place at the well, and the EPA continues to monitor the ground water at the site.

Fourteen sites are listed under the authority of HSCA: eight are considered ‘Low Priority’ (there is no immediate known threat to human health or the environment), one needs no further action (following a series of investigations), and three are undergoing investigation and review. Additionally, four other sites in the Chesapeake Basin are under the authority of the VCP.

Additional information regarding the sites mentioned in this section may be obtained from the accompanying Site Index Database, from the SIRB Web Site (http://www.sirb.awm.dhrec.state.de.us), or from the Site Investigation and Restoration Branch directly.

Source Type: Underground Storage Tank Sites

Leaking underground storage tank (UST) sites have been the source of over 2,000 reported releases of chemical contaminants into Delaware’s environment for the past 20 years. Contaminant releases often result from:

- Corrosion, breaks, ruptures or other types of structural damage in the tank or associated piping, dispensers, or other tank system components;
- Loose fittings in the tank system piping, associated dispensers, or other tank system components; or
- Spills and overfills that routinely occur during tank filling and dispensing operations.

Except for spills and overfills, contaminants are released below ground, and no release may be suspected by the tank owner or operator as many tank leak rates are often very low compared to the amount of fuel dispensed. Unless the tank is equipped with properly functioning leak detection equipment, and unless the operator is trained to use such equipment properly, leaks can continue unnoticed for many years. Such leaks continued undetected until a sensitive receptor, such as a well water (i.e., drinking water), utility line, or a building basement (explosive situation) has been impacted. By that time, the area that was impacted may have been severely environmentally damaged, and resulting site remediation costs escalated to several million dollars.

Released contaminants (including petroleum products) migrate downward through backfill, soils, and sediments surrounding the tank to the water table. Most products stored in USTs have a specific gravity that is less than one. As a result, any free-phase product that makes it to the water table not only floats on ground water but will migrate in the direction of ground-water flow. Because the water table in the Delaware portion of the Chesapeake Basin is often within 10 feet of the ground surface, a very small release from an UST may be sufficient to contaminate ground water. Once ground water becomes contaminated, the potential to impact domestic or public drinking-water wells increases, especially if these wells are screened in the water table aquifer. Surface-water bodies such as rivers, ponds, or lakes also can be impacted by a release from an UST facility.

UST site releases have become a growing concern in Delaware, including the Chesapeake Basin, over the past 20 years, especially because water wells and other sensitive receptors have been impacted.

Most UST systems in Delaware store petroleum products which include, but are by no means limited to: gasoline, kerosene, jet fuels, diesel fuel, heating oil, and used oils. USTs also may contain a variety of hazardous substances, such as chlorinated solvents.

Petroleum products can contain more than 100 different hydrocarbon compounds, many of which have been shown to be toxic to humans and wildlife. For example, benzene, a common constituent of gasoline, has been shown from epidemiological studies to be a human carcinogen. Benzo(a)anthracene and benzo(a)pyrene, which are common constituents of heating fuels, are probable human carcinogens.

Chemical compounds are commonly added to petroleum products to make these products burn more efficiently, and to reduce emission of toxic chemical compounds into the air. For example, the requirements of the Federal Clean Air Act Amendments of 1990 require that gasoline dispensed in Delaware contain up to 15 percent methyl tertiary butyl ether (MTBE). Unlike benzene and other hydrocarbon compounds present in petroleum, MTBE does not significantly biodegrade in the natural environment and dissolves into ground water much more easily,
thus making remediation more difficult. Dissolved MTBE molecules migrate through ground water much more rapidly than other hydrocarbon compounds. As a result, MTBE is usually one of the first chemicals from a release to impact drinking-water supplies. The EPA is currently conducting studies to determine if MTBE is a carcinogen. MTBE contamination is of great concern to the UST Branch because it has been documented in an increasingly greater number of new and existing leaking UST sites over the past few years.

There are currently 422 registered UST facilities and 235 identified leaking UST sites in the Chesapeake Basin. Seventy-two leaking UST sites are active, with the remainder closed or de-activated by the Department. Essentially, closed or inactive leaking UST sites are those sites where site investigation and remedial actions have been completed, and apparent threats to human health, safety, or the environment have been eliminated. Thus, the UST Branch requires no further action at closed or inactivated sites.

Although no data exist on the number of active sites in the Basin prior to 1997, it is likely that trends for the Delaware portion of the Chesapeake Basin are similar to those of the entire state. That is, available data show that the number of active sites statewide increased rapidly from 1983 through 1990, and then leveled off at about 550 sites. It is likely that the number of active sites will slowly decrease over the next several years.

Any UST site in the Basin, even one where no known release has occurred, is a potential source of contamination. Concern for releases is genuine, as even a small release can impact and degrade ground water due to occurrence of the water table so close to the ground surface. As a result, all registered UST sites in the Chesapeake Basin are included in the accompanying Site Index Database. Each registered UST site is also shown on Map 2.3-2 Known and Potential Chemical Sources – City Details.

It is important to note that not every UST in the Chesapeake Basin is registered with the Department. This includes UST facilities that are “exempt,” under current regulations, from registering with the Department. Most of the “exempt” USTs are heating oil tanks with capacities of 1,100 gallons or less for which no leaks or releases have occurred. Once a release has occurred, an “exempt” UST becomes regulated and the release must be cleaned up to levels that are not a threat to human health, safety, or the environment (as required at any leaking UST site). The Department has documented many cases of releases that have occurred in previously “exempt” tanks, and where stringent site remediation was required. Therefore, any currently “exempt” tank also has release potential.

Releases from “exempt” tanks are more difficult to detect and track because the Department does not regulate them. Detection occurs only during property transfer proceedings or after a sensitive receptor such as a water well is impacted. Thus, it is likely many releases have occurred from “exempt” tanks that the Department is not aware of, whereas those from regulated tanks under similar circumstances would likely be known. The relative lack of release data for “exempt tanks” represents a major data gap at UST sites.

Ground-water contamination has been documented in 56 leaking UST sites in the Chesapeake Basin. Severe ground-water contamination, including the presence of free-phase hydrocarbons, has been documented for 22 of these sites. Off-site contaminant migration has been observed at six sites.

Current UST regulations require that any UST installed after 1985 must comply with “new” tank standards, including protection against corrosion, and be equipped with spill and overfill protection and leak detection equipment. New tank systems cannot be put into operation until they pass a precision tank test (which is used to determine if a tank is leaking). Those tanks installed before the regulations went into effect in 1986 must have been either upgraded to comply with new tank standards before 1991 (except for corrosion protection) or be removed from the ground. Existing tanks still not equipped with adequate corrosion protection by 1998 must be either upgraded to comply with new tank standards before 1991 (except for corrosion protection) or be removed from the ground. Existing tanks still not equipped with adequate corrosion protection by 1998 must be either upgraded to comply with new tank corrosion protection requirements or be removed. Inventory control, recordkeeping, precision tank testing, as well as monitoring of leak detection equipment (including vapor and observation wells) and corrosion protection equipment, are required by owners and operators of all regulated USTs.

One of the major challenges of the Underground Storage Tank Branch is to (1) ensure that tank owners and operators bring their tanks into compliance with the regulations; (2) report any releases; and (3) effectively remediate contamination released at UST sites.

UST facility and leaking UST site records are available to the public through the Freedom of Information Act (FOIA) process. Anyone who wishes to review information regarding a specific UST site or has any questions regarding current UST regulations or UST Branch policies and guidelines should contact the UST Branch.

Source Type: Large On-Site Community Disposal Systems

Large community septic systems are a potential source of chemical contamination. The typical contamination is consumable salts, especially chloride (Cl). However these systems can also act as rapid pathways for various household chemicals (degreasers, cleansers, etc.) to the subsurface.

Source Type: Land Application of Wastes

Land application sites can vary in regard to their chemical constituent concentrations. The main chemicals of con-
cern in the Chesapeake Basin for industrial facilities are sodium and chloride. Chloride is also a potential contaminant from domestic wastewater facilities. Although many treatment systems receive other chemicals from domestic wastewater, the treatment process generally removes any chemical contaminants through aeration, volatilization, and chemical breakdown prior to land application.

**Source Type: Dredge Spoil Areas**

*Chesapeake and Delaware (C&D) Canal.* The C&D Canal is a navigational waterway to the Port of Baltimore maintained by the U.S. Army Corps of Engineers. The canal system provides a continuous sea-level channel connecting the Port of Baltimore to the northern ports of Wilmington, Philadelphia, and northern trade routes.

The federal government owns nearly 9,000 acres along the Chesapeake and Delaware Canal, and leases roughly 180 acres. The leased federal land is used for agricultural (39 acres) and disposal purposes, as well as for habitat and recreational purposes. Most of the unleased federal land (5,426 acres) along the canal is used for disposal of material resulting from maintenance dredging performed to sustain the authorized channel dimensions. *Map 2.3-2 Known and Potential Chemical Sources* shows locations of the dredge disposal areas.

Man-made embankments along the canal are the result of years of disposal activity and maintenance to authorized canal depths. Through a series of agreements, the states of Delaware and Maryland manage approximately 7,500 acres of property for recreation and wildlife management. These areas encompass historically filled disposal areas as well as many active (diked) disposal areas.

Nineteen upland disposal sites have been actively used by the federal government over the last 25 years for maintenance dredging of the Chesapeake and Delaware Canal. A 10-year monitoring program was initiated in 1987 to monitor heavy metal concentrations in vegetation, surface water, and ground water. DNREC and the Maryland Department of Natural Resources conduct soil, groundwater, and surface-water sampling on a regular basis. To date, results show the sampled media is not an environmental concern.

*Nanticoke River.* Dredging operations within the Nanticoke River Basin are conducted by the U.S. Army Corps of Engineers and confined to the main stem of the Nanticoke River between its mouth at Tangier Sound/Chesapeake Bay, Maryland, and the Route 13-A bridge at Seaford and Blades, Delaware. In addition, two Nanticoke tributaries, Marshyhope Creek and Broad Creek, have been dredged. With the exception of Broad Creek, the Corps has continued to maintain navigable depths in these waterways because of the vital role they play in economic development and growth. During the 1980s, the Corps implemented two maintenance-dredging projects to alleviate shoaling conditions hindering commercial shipping activities in the river. In 1983, one such project involved removal of 30,000 cubic yards of material from the Hawks Nest Shoal area of the main channel and from the section between Turtle Creek and the Seaford Harbor. Another project initiated in 1989–90 dredged over 50,000 cubic yards of material between Turtle Creek and the Harbor.

Sussex County provided confined disposal facilities to retain the dredge material from the above two projects. In 1983, the County secured a 6-acre tract of upland near the Delaware-Maryland State Line, and, in 1989, secured a 25-acre tract of upland on property owned by the DuPont Company. *Map 2.3-2 Known and Potential Chemical Sources* shows locations of these disposal facilities. Records of areas used for disposal before 1980 are not readily available, but there is speculation that Prickly Pear Island was created as a result of dredging activities in the downstream portion of the Nanticoke River.

**Source Type: Salvage Yards**

Automobile salvage yard and scrap metal recycling facilities provide a valuable service by recovering and recycling usable materials from discarded vehicles and equipment. While salvage operations are beneficial, the associated products and generated wastes have the potential to harm human health and the environment. Products and wastes from salvage operations include used oil, antifreeze, spent solvents, refrigerants, petroleum fuels, lead-containing wastes (e.g., batteries), tires, automobile fluff, and other solid wastes. Mismanagement of these products and wastes contributes to soil, water, and air pollution. Additionally, data linking the mismanagement of salvage materials containing polychlorinated biphenyls (PCBs) to the degradation and contamination of water systems exist. PCB contamination is responsible for the continued fish advisory precautions placed on numerous water bodies throughout Delaware. The Site Index Database contains information about the automobile salvage yards identified in the Chesapeake Basin. For more information regarding automobile salvage yards, contact the Hazardous Waste Management Branch.

**Source Type: National Pollutant Discharge Elimination System (NPDES) Reporting Facilities**

Municipal and industrial sites that discharge wastewater to surface waters are subject to limitations, monitoring requirements, and other terms and conditions identified in the individual NPDES permit issued to each site. Individual permittees must report monitoring results monthly, using the Discharge Monitoring Report (DMR) form developed specifically for each facility. The DMR lists parameters in the discharge that have a reasonable potential to cause or contribute to water-quality problems.
in receiving waters. Example parameters are temperature, dissolved oxygen, pH, copper, oil and grease, benzene, and PCBs. Although the DMRs are submitted monthly, actual monitoring frequency ranges from “continuously” to “once per year,” depending on the discharge’s characteristics and its volume relative to the receiving waters. Table 2.3-3 shows the list of currently active sites.

Industrial sites that discharge only storm water may be permitted under an NPDES General Permit, which is a single permit that applies to a group of similar dischargers, e.g., trucking operations. Monitoring for storm-water discharges is typically less frequent, for example, three times in five years.

**Source Type: Combined Sewer Overflow (CSO)**

Combined sewers are designed to carry both sanitary sewage (wastewater from domestic, commercial, or industrial sources) and urban storm-water runoff and to convey the “combined” sewage and storm-water flow to the treatment facility.

Combined sewer overflows occur during wet weather events when the combined sewerage and storm-water flows exceed the hydraulic capacity of the sewer system. CSOs are designed to relieve the sewer system of the excess flow and discharge it directly to a tributary or stream channel.

**Source Type: On-Site Septic Systems**

Septic systems are the main method for treatment of domestic wastewater used in the rural or unsewered areas of the Chesapeake Basin. In portions of unsewered sections, especially rural homesteads and older subdivisions, cesspools are still being used. Most are undocumented. A cesspool is usually a large, open-bottomed tank, which drains both liquid and solid wastes directly underground. A septic system is a more engineered waste disposal system compared to a cesspool and is usually comprised of a septic tank for solids and a distribution box and drainage field for liquids. The drainage field may be either gravity-fed or pressure-dosed.

Although domestic wastewater can contain a wide range of substances, its chemical composition is relatively simple compared to municipal wastewaters, which obtain liquid wastes from a variety of sources including housing, commercial, and industrial activities. Potential contaminants in domestic wastewater include dissolved organic matter, heavy metals, biological oxygen demand (BOD), pathogenic microorganisms, and soil nutrients such as nitrogen and phosphorus.

### 2.3.4 OVERALL CONTAMINANT FINDINGS

#### 2.3.4.1 Nutrients

Research in the Nanticoke watershed indicates that a notable amount of nitrogen loading (14.1 – 28.2 lbs/acre/yr) may be originating from septic systems. As the soil types and water table depths in the Nanticoke watershed are similar to the rest of the Chesapeake Basin, similar nutrient loads can be expected throughout the Basin. Overall, large community septic systems do not appear to be a significant problem. The majority of these systems are maintained and monitored by licensed operators. This requirement enables the Department to detect contaminant contribution to ground water and subsequently correct the related operational problems.

Monitoring data from land application of wastes from municipal and industrial sources indicate a decrease in nutrient over-application vs. conventional farming fertilization practices; nitrate reduction in ground-water recharges; and decreased nitrate in stream discharges.

Of the two operating municipal solid waste landfills owned by the Delaware Solid Waste Authority, routine ground-water and surface-water monitoring shows no significant nutrient releases.

Based on assessment data, the DuPont Seaford Nylon Plant is identified as a large point source for nitrogen and the largest point source for phosphorus. The TRI reports that, in 1998, DuPont Seaford released 669,000 pounds of nitrates from its on-site wastewater treatment plant, down from the 1,090,000 pounds reported in 1995. No earlier data are available from the facility to further define trends.

A major source of nutrient loading in the Chesapeake Basin is agriculture, the poultry industry, in particular. The recently completed poultry house inventory shows that there are approximately 750 poultry farms in the Basin. These farms are concentrated in specific areas (rather than spread out across the Basin). A resulting problem is that manure, too expensive to transport due to its bulk, is also concentrated in these areas.

The Broad Creek subwatershed has the state’s highest density of poultry activity per acre, as well as largest area of cropland. Total manure distribution for this subwatershed alone is estimated at 100,000 tons/year. Based on Broad Creek’s cropland acreage (40,886 acres), the manure application rate would be 2.4 tons per acre, which would appear to pose no environmental problems since the State of Delaware nutrient management recommendations allow for up to 4 tons per acre. This is assuming that this 40,886 acres of available cropland is grown in corn with recommended crop nitrogen needs of 175 lbs/ac/yr. In this scenario, the nitrogen application rate would be 175 lbs/ac/yr, and the phosphorus application rate would be 212 lbs/ac/yr. The recommended crop needs for phosphorus are only 40 – 45 lbs. This excess phosphorus is leaving the cycle in some fashion — either entering surface waters attached to sediment particles or leaching into the ground waters through phosphorus-laden soils.
The above scenario is not realistic because not all available crop acreage is grown in corn in this subwatershed. This scenario also does not take commercial fertilizer applications into consideration or that many times nitrogen from poultry manure is not credited as part of the overall crop needs. This means that someone may be applying the recommended 175 lbs of nitrogen per acre of commercial nitrogen, while also applying 4 tons of manure. Another factor to take into consideration is that crops such as soybeans and small grains that are grown in the Broad Creek subwatershed do not require the same high nitrogen inputs as corn.

In summary, the inability of crops to utilize all available nitrogen, combined with the predominance of sandy soils, leads to nitrogen loss through leaching or through volatilization as ammonia gas. Phosphorus is a serious issue that needs to be looked at closely in nutrient management planning and should be considered a limiting factor for determining overall manure application rates.

2.3.4.2 Chemicals
A large number of chemical contaminants are present in the Chesapeake Basin. They include the following:

- Heavy metals, such as iron, arsenic, cadmium, chromium, manganese, nickel, lead, barium, and zinc;
- PCBs;
- Solvents, degreasers, and paint thinners;
- Petroleum products such as gasoline and heating fuels;
- Pesticides and herbicides; and
- Other inorganic compounds such as chlorides and sulfates.

Contaminant source types present in the Chesapeake Basin include the following:

- Agricultural (pesticide mixing, loading, and storage locations);
- Landfills;
- Tire piles;
- Hazardous waste generators;
- Hazardous chemical inventory sites;
- TRI reporting facilities;
- Superfund sites;
- Leaking underground storage tank (UST) sites;
- Large on-site community septic systems;
- Spray irrigation sites;
- Dredge spoil areas;
- Salvage yards;
- NPDES point source dischargers.
- Combined sewer overflows, and
- Small on-site septic systems.

Not all sources have had actual releases, but are listed nonetheless because they have the potential to do so.

Chemical releases in the Chesapeake Basin have been documented at landfills, some hazardous waste generators, TRI facilities, Superfund Sites, UST sites, and salvage yards. These sites are under various stages of investigation/remediation, including:

- Undergoing corrective action;
- Contained and controlled;
- Monitored;
- Currently on hold but still active (because they are low-priority sites), or
- Inactive due to cleanup or because contamination remaining does not pose a threat to human health or the environment.

Many sources listed above have the potential to release chemicals into the environment. For some of these potential sources, engineering measures have been taken to minimize or prevent releases. Other potential sources have installed monitoring devices to provide early detection and cleanup of releases before they impact human health or the environment.

Some contaminant sources, such as pesticide mixing and loading facilities, have no data currently available. Part of the reason for this is that these sites are not currently regulated, either by the state or by EPA. Such data gaps make it difficult, if not impossible, to determine whether releases to the environment have occurred at these sites.

2.3.5 DATA GAPS AND RECOMMENDATIONS
2.3.5.1 Nutrients
1. Continue to promote and financially support conservation planning in the Chesapeake Basin and use COM-PAS GIS technology to document implementation of Best Management Practices.

2. Promote expansion of the state cost-share program, State Revolving Fund (SRF) and federal cost-share programs to cover innovative Best Management Practices and technologies for improved nutrient management in the state and in priority watersheds. For example, provide cost-sharing on poultry litter movement from areas of high concentration to areas where it can be utilized to meet crop needs, or offer low-interest loans to poultry companies to retrofit feed mills for nutrient reduction in poultry litter.

3. Targeted ground-water monitoring should be incorporated more frequently into projects. If possible, monitoring plans should be developed to discern short-term effects and predict long-term trends to provide a better indication of implementation impact.
4. Implement a cover-crop program throughout the Chesapeake Basin that includes educating farmers on the water-quality benefits of cover crops. Provide technical assistance and financial assistance through the state cost-share program.

5. Implement the Conservation Reserve Enhancement Program (CREP) in the Chesapeake Basin on 2,000 to 3,000 acres by the year 2002 for the following Best Management Practices (BMPs): filter strips, riparian buffers, wildlife habitat restoration, and shallow wildlife areas.

6. Evaluate current management practices used for agricultural drainage ditches. Data have shown that sediments in ditches represent an immediate source of particulate P and, as climatic conditions become favorable (i.e., warm and anoxic), a source of soluble P.

7. Consider how soil conservation and water management practices together affect the potential for P transport. For example, maintaining water levels in the ditches (and thus the adjacent fields) increases the potential for P losses in erosion and runoff by decreasing the infiltration capacity of soils. High water tables in soils also promote desorption and transport of subsoil P, and can cause reducing conditions that may induce the release of Fe-bound P from soils and sediments. We need to carefully re-evaluate how we now manage drainage to avoid creating water-quality problems based solely on water-quantity issues.

8. Promote new phosphorus management strategies (such as the “Phosphorus Index”) that consider both agricultural profitability and environmental quality. The Phosphorus Index evaluates eight characteristics to obtain an overall rating for a site. Each characteristic is assigned an interpretive rating based on the relationship between the characteristic and the potential for P loss from a site. The site characteristics are soil erosion; irrigation erosion; soil runoff class; soil test P value; P fertilizer application rate; P fertilizer application method; organic P source application rate; and organic P source application method.

9. Implement a phosphorus-based and nitrogen-based nutrient management system. Phosphorus-based nutrient management plans should be used for fields that have excessive soil-test phosphorus levels and a strong potential for phosphorus loss based on the Phosphorus Index.

10. Minimize nonpoint source pollution of surface waters by P from agricultural cropland using management practices that control both the supply and transport of soil P. The basic objective of environmentally sound P management is to maintain soil P fertility levels in a range that is optimum, but not excessive, for crop growth, while reducing the loss of particulate and soluble P by processes such as erosion, runoff, and drainage. Determination of the Phosphorus Index for soils that are near sensitive surface waters is the first step in this strategy, because this prioritizes the efforts needed to reduce P losses. Once this has been done, management options that are appropriate for soils with different P Index ratings can be implemented.

11. Focus nutrient management plans for intensive animal-based agriculture on farm-scale nutrient balance rather than exclusively on field-scale crop response to nutrients applied in animal wastes. Nutrient management plans that balance farm-scale nutrient inputs and outputs avoid on-farm nutrient accumulations, minimize the impact of off-farm nutrient losses, and optimize economic returns. When nutrient inputs to a farm exceed nutrient outputs, either inputs must be reduced or outputs must be increased to obtain a nutrient balance. For poultry-grain agriculture in Delaware, reducing inputs may include decreasing nutrient supplements in feed (e.g., using supplemental phytase or low-phytate corn feed); maximizing feed efficiency to reduce waste; and eliminating unnecessary fertilizer applications to fields. Increasing outputs may include developing off-farm uses of poultry litter as alternatives to land application (e.g., value-added products, bio-energy, poultry manure composting or pelleting, or the use of poultry litter in synthetic topsoils). Even when inputs and outputs can be balanced, efficient on-farm use of nutrients is still needed to prevent nonpoint losses of nutrients to the environment.

12. The Department should closely monitor Maryland’s Pfiesteria Action Plan as it contains proposed land-based solutions to the overall nutrient-loading problem. Governor Glendening’s Citizens Pfiesteria Action Commission has the following recommendations for agriculture:

a. The Commission recommends that Maryland adopt a phosphorus-based and nitrogen-based nutrient management system. Phosphorus-based nutrient management plans should be used for fields that have excessive soil-test phosphorus levels and a strong potential for phosphorus losses based on a phosphorus index.

b. The Commission recommends that Maryland enroll all farmers in nutrient management plans by the year 2000. These nutrient management plans should be fully and demonstrably implemented by 2002, contingent upon the Maryland supplying the appropriate level of education, outreach, technical support and financial resources necessary to meet these goals.

c. The Commission recommends that the Governor convene an oversight committee consisting, at a minimum, of the Secretaries of the Departments of Agriculture, Natural Resources and the Environment, a member of the Senate of Maryland, and a member...
of the House of Delegates to oversee the development and implementation of appropriate nutrient management programs and Best Management Practices.

d. The Commission stresses the importance of developing alternative uses for manure in conjunction with the movement to nitrogen-based and phosphorus-based nutrient management planning.

e. In order to make immediate progress in the redistribution of manure, the Commission recommends the establishment of a pilot program aimed at transporting chicken manure from the lower Eastern Shore.

f. The Commission believes that copies of all nutrient management plans be submitted to the Departments and to the Cooperative Extension Service in its role as a scientific and education agency, in a manner that protects the privacy of the individual farmer. The Commission also believes that nutrient planning standards and guidelines developed by the University of Maryland be utilized by all Cooperative Extension Service planners and private sector planners.

g. The Commission strongly recommends that phytase be added to feed supply as soon as possible. The Commission encourages the industry, Maryland, surrounding states, and the federal government to work together to implement the necessary technology as soon as possible.

h. The Commission recommends that Maryland (and surrounding states) establish a cost-sharing program to assist in the conversion of feed mills.

i. The Commission recommends that the MACS Program (cost-share) be expanded to allow non-animal growers who store and apply manure to be eligible to receive state assistance for the construction of manure storage sheds. Maryland need not invest money in such structures if the land on the requesting farm does not need additional phosphorus (as determined by the recommended phosphorus-based nutrient management plan).

j. The Commission encourages industry and the University System of Maryland to develop and, when appropriate, implement the use of litter treatments that will stabilize manure phosphorus into environmentally inactive forms.

k. The Commission recognizes that the use of low-phytic acid corn may be a viable and important part of the effort to reduce the phosphorus content of manure.

l. The Commission encourages expedited research into composting, post-composting processing, and the market potential of a composted product. The Commission urges industry, Maryland, and the private sector to collaborate on these solutions.

m. The Commission is encouraged by the prospect of burning the manure and encourages further research and demonstration on this issue. Fuel needs can likely be met on a large scale, as it is being explored by the Maryland Environmental Service and the Department for the Eastern Correctional Institute, or on smaller scales, as evidenced by the demonstration project examining the use of poultry litter as a fuel source for heating broiler houses. Burning litter disposes of the manure and leaves a certain amount of ash that can be used to either make artificial soils, serve as a component of a fertilizer mix, or serve as a poultry feed additive.

n. The Commission encourages the University of Maryland and the Department of Agriculture to work with the agricultural community to evaluate the effectiveness of current agronomic practices (such as no-till) to balance the techniques for minimizing soil erosion, surface-water runoff, and leaching of nutrients from agricultural land.

o. The Commission is encouraged by federal and Maryland’s efforts to increase resources for the Conservation Reserve Enhancement Program (CREP). This program will provide increased payments to farmers who treat certain environmentally sensitive land in order to voluntarily restore wetlands, establish stream buffers, and retire highly erodible land from production.

p. The Commission urges Maryland to aggressively market CREP and to sponsor outreach and educational programs designed to maximize farmer participation. The Commission encourages all interested Marylanders to participate in publicizing this voluntary opportunity.

q. The Commission encourages the University of Maryland to work with the agricultural community to establish demonstration projects and to conduct expedited research into drainage ditches. In soils where soluble phosphate is reaching drainage ditches, it is theoretically possible to chemically precipitate the phosphorus out of the water by using crushed limestone. The cost associated with this technique should be minimal, but the chemical dynamics of the procedure need to be better understood before its use can become widespread.

r. The Commission encourages the University of Maryland and the Department of Agriculture to continue research and demonstration projects in the area of tillage as a site-specific technique for reducing phosphorus levels in the upper layers of soil. Tillage would "turn over" the soil, burying the phosphorus below the soil surface, but within the root zone of the crop. In order for this technique to
work, the subsurface soils must have lower phosphorus content than the surface soil and the subsurface soil must be conducive to supporting crop production.

The Commission strongly encourages the regular use of cover crops as a Best Management Practice. Research has shown that nitrate-leaching losses occur even when all crop-yield goals are met and all Best Management Practices and a nutrient management plan are implemented. It is estimated that the utilization of a cereal grain cover crop following a corn or soybean crop can reduce nitrate-leaching losses by 50 percent.

The Commission strongly recommends that Maryland implement a continuing cover-crop program designed specifically to limit nitrate leaching and to prevent nutrients from entering the bay and its tributaries. The Commission encourages the federal government to provide support for Maryland’s cover crop program, possibly through the Environmental Quality Incentive Program.

The Commission believes that participation in MACS cost-sharing programs in place for manure sheds, dead bird composters, and CREP improvements, as well as programs addressing cover crops and nutrient management planning, can be enhanced by increased outreach and technical assistance. The Commission encourages Maryland to provide an appropriate and meaningful level of support to the Department of Agriculture and the Cooperative Extension Service in order to increase the use of existing Best Management Practices and to otherwise implement the recommendations of this Commission.

13. With the widespread nutrient inputs throughout the Basin, it is important to locate all of the various sources accurately so that local action can be taken. In particular, as population increases in rural areas, septic systems are installed to dispose of the waste. The regional density of these systems and their proximity to the sensitive resources are important pieces of the nutrient management puzzle. Therefore, all septic systems in the Basin (state) should be mapped using aerial photography. This information, when placed in GIS format, should be used to answer more specific questions about system placement and density.

14. Recommend use of septic mapping data in the development of Pollution Control Strategies (PCSs).

15. Recommend that the state develop Animal Feeding Operations (AFO) strategies (permits, BMPs, etc.).

16. Identify the areas where a significant amount of ground water is being consumed and the Department has little or no water-quality data.

17. Develop and implement pollution control strategies to meet established TMDLs for Nanticoke and Broad Creek.

18. Begin development of TMDLs for remainder of Basin.

19. Develop and implement storm-water monitoring plan.

20. Eliminate all Combined Sewer Overflows in Basin.

21. NPDES permit synchronization in watersheds/basins.

22. Review of septic regulations considering TMDL/PCS issues.

23. Work with counties and local governments to coordinate septic regulations for greater (average) open space for unserved areas.

24. Amend the septic regulation to provide for more appropriately located large community septic systems.

25. Recommend that the Department deny the placement of new (non-replacement) alternative septic systems outside of investment areas and restrict their placement in investment areas to reduce impacts to wetlands and important habitats.

26. Assess septic system failure rate for the Chesapeake Basin through remote sensing and verification by grounding survey.

27. Support and develop certification for (required) inspection of septic during property transfer.

28. Obtain grants to repair, or replace, malfunctioning septic systems in environmentally sensitive areas. Incorporate innovative technologies where appropriate.

29. Continue to research and demonstrate alternative systems, such as gray-water separation, or the placement of sawdust under tile drainage fields.

30. As the state moves to implement TMDLs and Pollution Control Strategies, it is very important that the lands the government owns or controls be managed properly. Therefore, all lands owned by state and federal governments should be assessed and have comprehensive conservation plans developed for them. These plans should then be incorporated into the land lease agreements and daily management practices.

31. Review analytical site data from all site types for any available nutrient information.

### 2.3.5.2 Chemicals

Based on a chemical contamination study of sediments for the Nanticoke River conducted by Greene (1997), several recommendations were made which would help characterize chemical contamination within the Basin:

1. The Department should coordinate with the U.S. EPA and the City of Seaford in the review of influent and effluent data generated in conjunction with the City’s Industrial Pretreatment Program for its wastewater treatment plant. The effluent data should be used to estimate mass loadings of toxics to the Nanticoke River from the treatment plant.
2. The Department should work with the DuPont Company to better characterize metals releases from the DuPont Seaford Nylon Plant to the river. Water and sediment samples should be collected downstream of the fly-ash polishing pond and analyzed for selected metals. These samples should be collected above the dam on DuPont’s property and below the dam within DuPont Gut. The magnitude, duration, and frequency of coal-pile runoff should also be assessed.

3. The Department should continue to work with the City of Seaford to ensure that the city’s Combined Sewer Overflows (CSOs) are eliminated in a timely manner.

4. The results of the Chesapeake Bay Fall Line Toxics Monitoring Program for the Bridgeville USGS gauge location suggest existence of sources for pesticides and metals entering the Nanticoke River above the Bridgeville gauge. The Chesapeake Whole Basin Team should review and map out available pollutant source data for that area of the watershed above the Bridgeville gauge. The relative importance of these sources in comparison to sources in the Seaford area should be considered within an overall mass balance context.

5. An assessment should be made of the potential for silver iodide to enter the Nanticoke River from agricultural supply operations.

6. Delaware should contact the Army Corps of Engineers and request a summary of the nature and extent of shipping activity on the Nanticoke. Information that would be of use includes the annual volume and type of products transported to and from the Seaford area; a description of off-loading practices used at the various docking facilities; a summary of spill reports and cleanup response; a description of past dredging activities; and a schedule for future dredging activities.

7. The Department should evaluate the extent to which Best Management Practices are being implemented for bulk chemical transfer and storage along the Seaford waterfront.

8. Educate the public regarding the proper disposal of motor oil and household chemicals. Continue to support the efforts of the Delaware Solid Waste Authority in its household hazardous waste collection program.

9. Place EPCRA Tier II facilities on the chemical contaminants map and also populate the Site Index Database with these sites.

10. The extent to which metals contamination of the sediment is also a problem in the water column is not well characterized. Historical water column metals data should be compiled and assessed in conjunction with the Preliminary Assessment Report.

11. Provide technical assistance to the city of Seaford for the installation of “urban BMPs” such as sand filters and other passive storm-water pollutant reduction devices.

12. Implement a storm-drain stenciling program to raise the awareness of the public concerning the relationship between storm-water runoff and river quality.

13. Aboveground storage tanks are currently unregulated; develop regulations for operation, spill/overflow protection, leak detection, tank testing requirements, and corrosion protection.

14. A sediment “Triad” study should be conducted in the reach of the Nanticoke River below Seaford to confirm or refute whether sediments are actually toxic to benthic organisms.

15. Deep (e.g., 3’ – 5’) sediment cores should be obtained and analyzed at discrete depth intervals in an effort to determine the historical input and sedimentation rate of PCBs and heavy metals in the Nanticoke below Seaford.

16. Develop education process for owners of exempt Underground Storage Tanks about proper maintenance and leak detection to avoid becoming a regulated LUST.

17. Explore options for acquiring the needed support to produce comprehensive periodic inventories of greenhouse gases.

2.3.6 REFERENCES


2.4 AIR QUALITY

2.4.1 INTRODUCTION

In 1970, Congress amended the Clean Air Act of 1963 and authorized the EPA to establish National Ambient Air Quality Standards (NAAQS) for pollutants shown to threaten human health and welfare. Primary standards were set according to criteria designed to protect public health, including an adequate margin of safety to protect sensitive populations (e.g., children, asthmatics, and the elderly). Secondary standards were set according to criteria designed to protect public welfare (decreased visibility, damage to crops, vegetation, buildings, etc.).

Six principal pollutants currently have NAAQS: ozone (O₃), carbon monoxide (CO), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), particulate matter (PM₁₀), and lead (Pb). These are commonly referred to as the *criteria pollutants*. When air quality does not meet NAAQS, the affected area is said to be in non-attainment with NAAQS. Currently, there are no standards for acid rain, nitrogen deposition, or air toxics.

Delaware’s land surface is relatively flat, and because of this condition, outdoor or ambient air moves fairly smoothly through and is generally well mixed across the entire state. The predominant airflow is from west to east. In the summer, southwesterly winds prevail while in the winter northwesterly winds are dominant.

2.4.1.1 Status

**Pollutant levels**

Air quality in the Chesapeake Basin meets all NAAQS except for ozone, with PM₁₀ status yet to be determined. New Castle and Kent counties are classified as serious non-attainment areas for ozone while Sussex County meets the one-hour standard, but not the new eight-hour standard. Acid rain monitors outside the Chesapeake Basin show precipitation to average around pH 4.2 to 4.3 (acidic).

Delaware has one air monitoring station located within the Chesapeake Basin. This station is located at the Shipley State Service Center in Seaford. Pollutants monitored include ozone (April through October), sulfur dioxide, and particulate matter. Descriptions of these pollutants, as well as their health effects, are summarized as follows.

**Ozone (O₃)**

Ozone is a highly reactive gas that is the main component of smog. While ozone in the upper atmosphere (stratosphere) is beneficial because it absorbs ultraviolet light, it is considered a pollutant in the lower atmosphere (troposphere). It is a strong respiratory irritant that affects...
healthy individuals as well as people with impaired respiratory systems. It can cause respiratory inflammation and reduced lung function. It also adversely affects trees, crops (soybeans are a particularly sensitive species), and other vegetation. Ozone is also implicated in white pine damage and reduced growth rates for red spruce at high elevation sites.

Ozone is not emitted directly by a pollution source but is formed in the atmosphere by the reaction of nitrogen oxides and volatile organic compounds in the presence of sunlight and warm temperatures. Therefore, ozone is basically a problem only in the summer months. In Delaware, the season for ozone monitoring runs from April through October.

Ozone trends are difficult to measure because of the complex nature of weather. In general, ozone concentrations in recent years (1990s) have been significantly lower, with fewer exceedances of the standard, than during similar weather patterns in the 1980s. Improvement is due to corrective measures such as improved pollution controls on large industrial sources, vapor recovery on gasoline pumps, and lower volatility of gasoline and various solvents.

Sulfur Dioxide (SO₂)

Sulfur dioxide is a pungent, poisonous, colorless gas. It is an irritant that can interfere with normal breathing functions, even at low concentrations. It aggravates respiratory diseases such as asthma, emphysema, and bronchitis. The severity of these condition can be magnified as particulate levels increase. Sulfur dioxide can also cause plant chlorosis and stunted growth.

Sulfur dioxide levels declined rapidly in the 1970s and have remained fairly steady over the last 10 years. Figure 2.4-1 depicts the trend at the Seaford monitoring station. The improvement is largely due to the change to low or lower sulfur fuels in power plants as well as to improved emission control technologies.

Particulate Matter (PM₁₀)

PM₁₀ is the portion of total suspended particulates that is less than 10 microns in diameter and thus, small enough to be inhaled into the lungs. PM₁₀ can include solid or liquid droplets that remain suspended in the air for various lengths of time. Particles small enough to be inhaled can carry other pollutants and toxic chemicals into the lungs. Major effects of PM₁₀ include aggravation of existing respiratory and cardiovascular disease, alterations in immune responses in the lung, damage to lung tissue, and premature mortality. The most sensitive populations are those with chronic obstructive pulmonary or cardiovascular disease, asthmatics, the elderly, and children. Particulates are also a major cause of reduced visibility and can be involved in corrosion of metals (acidic dry deposition).

There are other pollutants with NAAQS that presently are not monitored in the Chesapeake Basin, but are monitored elsewhere in Delaware. These pollutants include nitrogen dioxide, carbon monoxide, and lead.

Sources

The federal Clean Air Act Amendments of 1990 (CAA) required Delaware to inventory baseline air emissions.
Figure 2.4-3
DISTRIBUTION OF PEAK OZONE SEASON DAILY VOC EMISSIONS

<table>
<thead>
<tr>
<th>County</th>
<th>VOC Emissions (Tons/Day)</th>
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<tbody>
<tr>
<td>Kent County</td>
<td>60.7</td>
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<tr>
<td>New Castle County</td>
<td>125.0</td>
</tr>
<tr>
<td>Sussex County</td>
<td>84.3</td>
</tr>
</tbody>
</table>

Figure 2.4-4
DISTRIBUTION OF PEAK OZONE SEASON DAILY NOx EMISSIONS

<table>
<thead>
<tr>
<th>County</th>
<th>NOx Emissions (Tons/Day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kent County</td>
<td>26.1</td>
</tr>
<tr>
<td>New Castle County</td>
<td>146.7</td>
</tr>
<tr>
<td>Sussex County</td>
<td>85.2</td>
</tr>
</tbody>
</table>

Figure 2.4-5
DISTRIBUTION OF PEAK OZONE SEASON DAILY CO EMISSIONS

<table>
<thead>
<tr>
<th>County</th>
<th>CO Emissions (Tons/Day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kent County</td>
<td>109.0</td>
</tr>
<tr>
<td>New Castle County</td>
<td>380.4</td>
</tr>
<tr>
<td>Sussex County</td>
<td>152.9</td>
</tr>
</tbody>
</table>
beginning in 1990. Delaware must subsequently inventory air emissions every three years in order to show reasonable progress toward attainment of the NAAQS (see Addenda 1 and 2). These inventories are prepared on a countywide basis. Sources of air emissions are classified by the nature of the emissions and the physical characteristics of the emitter. Source categories of air emissions within the Chesapeake Basin for which data are collected include stationary point sources, stationary area sources, mobile sources, and biogenic sources. Figures 2.4-3 through 2.4-5 illustrate VOC, NO\textsubscript{x}, and CO emissions by county and source category.

The five source categories are defined as follows:

**Stationary Point Sources**
A stationary point source is defined as a facility that emits 10 tons per year (TPY) or more of volatile organic compounds (VOCs) or 100 TPY or more of oxides of nitrogen (NO\textsubscript{x}) or carbon monoxide (CO). (see Map 2.4-1 Air Sources)

**Stationary Area Sources**
Stationary area sources represent a collection of many small, unidentified points of air pollution emissions within a specified geographical area, all emitting less than the level attributed to stationary point sources. Since these sources are too small and/or too numerous to be characterized individually, all area sources must be identified and emissions from these activities collectively estimated. Area sources can be grouped into four types of general activity categories:

1. Fuel combustion sources;
2. Solid waste incineration and open burning sources;
3. Fugitive dust sources; and

**Mobile Sources**
Mobile sources of air emissions are divided into on-road and off-road categories of activity. On-road emissions are those attributed to all vehicular traffic active on the state’s highway network. Quantities of emissions are indirectly calculated through the use of both a travel demand model and a mobile emissions simulation model. The off-road emissions category includes a diverse set of source types. The movement of sources in this category occurs on surfaces other than the public highway system and includes the following sources: aircraft, locomotives, marine vessels, and other off-highway vehicles and equipment. These emissions are estimated through a series of complex simulation equations. Pollutant emissions estimated for these two categories during the statewide inventory process are VOCs, NO\textsubscript{x}, and CO.

**Biogenic Sources**
Biogenic air emissions are those which originate from naturally occurring sources, with vegetation being the primary contributor. Air pollutant emissions from these sources are estimated through a computer simulation model. As NO\textsubscript{x} and CO emissions from natural sources are negligible, only VOC emissions were estimated for this category during the statewide inventory process.

**Air Toxics Sources**
As required by the federal government, more than 650 toxic chemicals are subject to release reporting by industrial and manufacturing facilities on an annual basis. Sources of air toxics include many types of large and small industrial facilities, as well as mobile sources. The Toxic Release Inventory, prepared by the Department, contains annual data from specific larger industrial facilities that manufacture, process, and/or use toxic materials.

### 2.4.2 CENTRAL ISSUES

#### 2.4.2.1 Ozone

**Ambient Concentrations**
In the Chesapeake Basin, maximum ozone levels usually occur in the afternoon or early evening on hot, sunny days. During most high ozone days, the concentrations of ozone are greater in the northern part of the Basin and are often associated with light southwesterly winds. The highest ozone levels in the southern part of the Basin usually occur with a westerly wind that places towns in this area directly downwind of Washington, D.C.

In 1997, there were three days when ozone levels in the Town of Seaford (in the southern part of the Chesapeake Basin) exceeded the one-hour ozone NAAQS. The maximum ozone concentration was 0.132 ppm. The monitor located at Lums Pond evaluates the northern

<table>
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<tr>
<th>DATE</th>
<th>LUMS POND</th>
<th>SEAFORD</th>
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</thead>
<tbody>
<tr>
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<td>0.127</td>
<td></td>
</tr>
<tr>
<td>24 June</td>
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<td>25 June</td>
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<td>17 July</td>
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<td></td>
</tr>
<tr>
<td>28 July</td>
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<td>0.125</td>
</tr>
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</table>
part of the Basin. This monitor recorded four days with exceedances, and a maximum one-hour concentration of 0.146 ppm. It should be noted that the exceedance days in the northern and southern portions of the Basin occurred on different dates (see Table 2.4-1), reflecting the difference in prevailing wind direction on those days.

**Regional Transport Versus Local Sources**

The regional transport of ground-level ozone and ozone precursors over long distances is a recognized scientific fact and a serious regional problem in the eastern United States. For example, even if all emissions sources within the Basin were controlled, upwind sources such as Washington, DC, and Baltimore, MD, would still produce episodes of unhealthy air quality and exceedances of the NAAQS within the Basin. Consequently, the states involved are working together to address the problem.

Two organizations — the Ozone Transport Assessment Group (OTAG) and the Ozone Transport Commission (OTC) — were formed under the authority of the federal Clean Air Act to examine the mechanisms and likely controls of ozone transport within the United States. The OTAG, made up of representatives from the 38 states east of the Rocky Mountains, prepared a report outlining specific recommendations to the EPA for the control of the transport of ozone and ozone precursors. OTAG disbanded in June 1997. The OTC addresses ozone and ozone precursor formation and transport within the Ozone Transport Region (OTR), which extends along the Atlantic coast from Virginia to Maine. This commission currently maintains a full-time staff and is comprised of governmental leaders and environmental officials from all the member states, the District of Columbia, and the EPA.

**Effects on Agriculture/Ecosystem**

Ozone interferes with the ability of plants to produce and store food. Ozone weakens the plant and makes it more susceptible to injury from pests and other environmental stresses. Some species of plants are more sensitive to ozone than others. Susceptibility can also vary among individual plants within a species. Factors affecting the response of plants to ozone include environmental conditions (drought, soil conditions, etc.), presence of pathogens, and interactions with other plants, as well as the timing and duration of exposure to ozone. In general, studies of various crop species have shown that ambient ozone concentrations above the NAAQS cause decreases in crop yields.

Ozone also causes foliar (leaf) damage to plants. Trees that have been reported to show injury due to ozone include white pine, red spruce, and black cherry. Milkweed is another native plant species that is sensitive to ozone and has been used as an indicator of elevated ozone levels. Milkweed is also a good example of how ozone can impact an ecosystem. As milkweed is the only food source for the larva of the monarch butterfly, ozone damage to milkweed could indirectly affect the monarch butterfly population.

Vegetation damage from ozone is more strongly related to longer-term average levels of ozone than to one-hour peak concentrations. The new eight-hour primary standard for ozone is estimated to represent a level that would also be equally protective of plants. Therefore the secondary standard for ozone has been set equal to the primary standard.

**2.4.2.2 Pollutant Deposition**

Chemicals are removed from the atmosphere and deposited on surfaces through a variety of mechanisms. Deposition can occur through both wet (rain, snowfall, and fog) and dry processes. Both gases and particles can interact with water droplets as well as other chemical compounds to form contaminants that deposit in the Chesapeake Basin. As with ozone, atmospheric transport from varying distances plays an important role. The importance of atmospheric deposition to ecosystem health is becoming recognized, but knowledge of the related physical and chemical processes is minimal.

**Dry Deposition** — Dry deposition consists of any type of particle that is deposited on a surface. Organic as well as inorganic compounds and trace metals can be a part of this deposition. Delaware has yet to monitor dry deposition in the Chesapeake Basin.

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**Figure 2.4-6**

**NUMBER OF DAYS EXCEEDING OZONE STANDARD**

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Days</th>
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<tbody>
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<tr>
<td>1989</td>
<td>14</td>
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<td>4</td>
</tr>
<tr>
<td>1995</td>
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</tr>
<tr>
<td>1996</td>
<td>0</td>
</tr>
<tr>
<td>1997</td>
<td>0</td>
</tr>
</tbody>
</table>

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**Sulfur Compounds** — Sulfur dioxide can bind to dust particles and aerosols in the atmosphere, traveling long distances on the prevailing winds. It can be oxidized to a sulfate ion (SO₄²⁻) and combine with water vapor to form sulfuric acid and fall as acid rain. Sulfur compounds also contribute to visibility degradation. The only current monitoring of sulfur compounds in the Chesapeake Basin is for SO₂ (as described previously).

**Nitrogen Compounds** — Reactions between nitrogen oxides and other compounds in the atmosphere can form nitric acid, which contributes to the acid rain problem. Other reactions can produce nitrate compounds that affect visibility. Atmospheric deposition of oxides of nitrogen can be a significant source of nitrogen to estuarine systems. There is no current monitoring of nitrogen compounds in the ambient air of the Chesapeake Basin.

**“Acid Rain”**

Acid rain (more properly called acid precipitation) is rain, snow, or fog that contains sulfuric and/or nitric acids. It results from the reaction of sulfur and nitrogen oxides released from various combustion processes with water in the atmosphere to form acids. These chemical compounds can travel for many miles in the air before falling in acid rain.

The National Atmospheric Deposition Program (NADP) reported an improvement in the acidity of precipitation in 1995, particularly in the Mid-Atlantic and New England regions. Although there is no current monitoring of acid rain in the Chesapeake Basin, the NADP data indicate widespread improvements that include the area of the Chesapeake Basin.

**Nitrogen**

Nitrogen compounds deposited as either acid rain or dry deposition contribute to the total nutrient loading in a watershed. Studies conducted in the Chesapeake Bay Program indicate that 21 to 27 percent of the total nitrogen loading to the Chesapeake Bay is a result of atmospheric deposition. Computer modeling studies have defined the Chesapeake Bay Airshed (the region that contributes 80 percent of the deposition falling into the bay watershed) as approximately five times larger than the watershed. Recent studies also have indicated that industrial sources such as power plants contribute the largest portion of nitrogen deposition in the western part of the Chesapeake Bay watershed, while mobile sources contribute the largest portion of nitrogen in the eastern part, which includes the Delaware Chesapeake Basin (EPA, 1997).

Although Delaware does not monitor for nitrogen deposition in the Chesapeake Basin, data from the NADP monitors can be used to estimate deposition rates. Data from the latest annual NADP report show wet deposition rates of 6.8 kg/ha in the area of the Delmarva Peninsula (NADP, 1998).

### 2.4.2.3 Air Toxics

_Air toxics_ is a term often used to refer to chemicals that are toxic or suspected of producing a toxic response through human exposure. The complex chemical composition of these compounds, as well as the great number of them, makes comprehensive monitoring difficult. In northern Delaware, the Department has conducted limited monitoring for specific compounds in the City of Wilmington and in some areas near large point sources.

**Ambient Concentrations**

There are currently no national ambient air standards for air toxics. Ambient monitoring in the Seaford area is conducted by using sorbent tubes and analysis by GC/MS. Samples are collected for 24 hours every sixth day. Sampling began in January 1997 and ran through the end of 1998. Average concentrations of all chemicals monitored have been less than one part per billion (ppb). Results (through October 16) are shown in Table 2.4-2.

**Sources/Controls**

Three programs currently possess data and information regarding toxic air emissions from point sources within the Chesapeake Basin. Mobile sources of toxic air emissions other than VOCs, NOₓ, and CO are not quantified at this time.

**Annual Point Source Inventory** — This inventory is compiled annually. It covers emissions of VOCs, NOₓ, CO, SO₂, PM₁₀, TSP, and Pb from facilities that are major emitters or potential major emitters of at least one of these pollutants. This inventory has been generated since 1990 and covers 14 facilities within the Chesapeake Basin (refer to Site Index Database). Currently, 1990, 1992, and 1993 are completed; 1994 is in draft form. There are currently no written reports of these inventories, but emissions summary printouts can be generated from the computer database, I-STEMS.

**Toxic Release Inventory** — The Toxics Release Inventory (TRI) contains annual data from large industrial facilities that manufacture, process, or otherwise use toxic chemicals. Fourteen facilities located within the Chesapeake Basin (all within the Nanticoke Watershed) have reported to the TRI program since 1988. Twelve of these facilities have reported for 1998, the most current reporting year. Of these twelve, seven reported the release of toxic chemicals to the air. Refer to the Site Index Database’s facility list as well as 1996 air-release data from facilities.

The Permitting & Compliance Group of the Air Quality Management Section maintains air permits for various processes that emit air toxics. While these permits do not provide actual emissions data, they do provide information regarding the potential to emit and the controls that exist to reduce that emission. Specific toxic chemicals, called Hazardous Air Pollutants (HAPs), are regulated under these permits.
2.4.2.4 Changing National Ambient Air-Quality Standards

**Attainment vs. Non-Attainment**

The EPA defines reasonable progress towards attainment of the ozone standard as a 3 percent annual reduction in volatile organic compounds and/or NOx from 1990 levels (see Addendum 2). In 1994, the Department submitted a 15 percent Volatile Organic Compound Reduction Plan to the EPA. The plan targeted sources such as heavy industry, gasoline stations, and motor vehicles. As an example of reduction, companies were required to reduce volatile emissions from paints and solvents, and control leaks of volatile production materials and gases in manufacturing processes. Also, gasoline stations were required to capture emissions from refueling. Finally, the Department issued a summertime ban on all open burning. The plan also included a reduction in VOCs from the use of reformulated gasoline, a new type of fuel mandated by the federal government for use in ozone non-attainment areas.

Delaware must demonstrate, through complex atmospheric computer modeling, that it will attain the ozone standard by 2005. Many new strategies to control VOCs and NOx emissions will need to be implemented before the year 2005 to produce the necessary improvements in air quality. If Delaware fails to meet the mandated reductions in air pollutants, it will lose federal highway funding as well as face stricter emission controls prescribed by the EPA.

To meet the 2005 target, the Department estimates that both VOCs and NOx may have to be reduced by as much as 75 percent from 1990 levels. Alternative reduction strategies range from additional controls on dry cleaners and other small businesses to adoption of a far more comprehensive motor vehicle emission inspection and maintenance program and required sale of ultra-low polluting and electric cars. More emphasis also may have to be placed on controlling pollution from household and recreational sources such as lawn mowers, motor boats, and barbecue grills.

In response to new research on the effects of ozone on human health, the EPA revised both the form and the level of the ozone standard in July 1997. The new standard is an eight-hour average of 0.08 ppm. An area will attain this standard when the three-year average of the annual fourth highest daily maximum eight-hour concentration is less than or equal to 0.08 ppm. This standard will apply to all areas after they have met the one-hour standard as described above and have three complete years of monitoring data indicating attainment. Areas will not be officially designated as meeting or failing to meet the eight-hour standard until 2005 at the earliest. Current monitoring data indicate that the entire state of Delaware, including the Chesapeake Basin, will not meet this new standard.

**Fine Particulates**

In 1996, the EPA completed its review of the PM10 NAAQS. The result was a change in form of the PM10 standards and the addition of new annual and 24-hour PM2.5 standards. These new standards are based on recent studies showing human health impacts from fine particulates, or PM2.5, at...
levels lower than the existing PM$_{10}$ standards. The new standards are designed to emphasize monitoring and evaluation of community-wide levels of fine particulates.

Fine particles are generated mainly by combustion processes. Sources include large point sources such as fossil-fuel burning power plants as well as mobile sources (both on- and off-road). Fine particles can be emitted directly from a source (primary pollution) or form in the atmosphere from combinations of compounds (secondary pollution). They can travel long distances due to their extremely small size and behave almost like a gas. This means that long-distance transport is more important for fine particles than coarse particles and regional and/or national control strategies will be needed to address air-quality problems.

There are limited data on ambient levels of PM$_{2.5}$, and no monitoring has been conducted yet in Delaware. Existing PM$_{10}$ data indicate that Delaware will not meet the new fine particulate standard and that concentrations will probably be higher in the northern urbanized areas of the state.

2.4.3 POSITIVE INITIATIVES

2.4.3.1 Brief Discussion of the Clean Air Act of 1990 and Requirements

Although the 1990 Clean Air Act is a federal law covering the entire country, the states do much of the work required to carry out the specific provisions within the Act. These provisions include the development of State Implementation Plans which define what steps each state will take in order to comply with the NAAQS and progress toward the required ozone reductions by the year 2005 (see addendum).

Under this law, the EPA sets limits on how much of a pollutant can be in the air anywhere in the United States. This ensures that all Americans have the same basic health and environmental protections. The law allows individual states to have stronger pollution controls, but states are not allowed to have weaker pollution controls than those set for the rest of the country.

2.4.4 DATA GAPS AND RECOMMENDATIONS

1. Adequate information currently exists to evaluate status and trends for the criteria pollutants: sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead. Data collection and evaluation should continue unchanged.

2. The regional nature of the ozone problem makes it essential that state, regional, and federal agencies share data. Delaware currently works with other states, regional agencies, and the EPA to provide ozone data among the various states and agencies. The Department should continue these efforts.

3. Adequate information currently exists to evaluate the status and trends for PM$_{10}$. New particulate matter standards for PM$_{2.5}$ have been enacted by the EPA and require the development of baseline data from which future reductions may be calculated.

4. The periodic ozone precursor emission inventories for VOCs, NO$_x$, and CO are compiled every three years. The inventories are comprehensive and cover all emission source categories. Emission inventories for SO$_2$, PM$_{10}$, TSP, lead, and toxics are performed annually but only for large point sources. More comprehensive inventories of these pollutants with the addition of PM$_{2.5}$ are recommended in order to gain additional information on impacts to the Chesapeake and other basins. Impacts of emissions on the Chesapeake and other basins could also be improved by developing methods to enable aerial, mobile, and biogenic emissions to be illustrated in graphical form, such as on a Geographic Information System (GIS) map.

   a. Explore options for acquiring the needed resources to produce comprehensive periodic inventories of SO$_2$, PM$_{10}$, TSP, lead, and toxics.

   b. Develop a method to allocate aerial, mobile, and biogenic emissions to geographic basins, and graphically portray those emissions.

5. Atmospheric deposition is proving to be a major contributor to acidification, nitrogen loading, and toxification of waterways. There is currently little or no specific information on the impact of atmospheric deposition to the Chesapeake and other Delaware basins. It is recommended that options be explored for acquiring the necessary resources to conduct computer modeling and other research to quantify the impact of atmospheric deposition on the Chesapeake and other basins.

6. National studies have shown that high ozone levels cause crop damage and reduce yield, thus adversely impacting our food supply and causing millions of dollars in losses to the agricultural community. Little or no information is available on the level of crop damage and associated impacts on the Chesapeake and other Delaware basins. It is recommended that options be explored for acquiring the necessary resources to study and quantify the level of crop damage and associated impacts on the Chesapeake basins.

2.4.5 REFERENCES

NADP. 1998. *National Atmospheric Deposition Program (NRSP-3)/National Trends Network*. NADP Program Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, IL 61820

2.4.6 ADDENDUM #1 –
EMISSION ESTIMATION APPROACH

2.4.6.1 Point Sources

A point source is defined as a stationary source facility that emits at least 10 tons per year (TPY) of volatile organic compounds (VOCs) or 100 TPY or more of NO$_x$, CO, SO$_2$, PM$_{10}$, total suspended particulates (TSP), or lead. The point source inventory represents estimated emissions from these facilities.

In general, one of three estimation methods is used. In order of preference, the estimation methods are (1) stack testing or continuous emissions monitoring; (2) material balance calculations; and (3) emission factor calculations based on units of throughput or activity. All data necessary to make the emissions estimations are collected by means of annual reporting by the facility. All point source data are entered into a computer database called I-STEPS.

2.4.6.2 Stationary Area Sources

Area source emissions are compiled once every three years for the Ozone State Implementation Plan (SIP) Inventory. The pollutants covered are VOCs, NO$_x$, and CO. Area source emissions are estimated by multiplying an emission factor by a known indicator of collective activity for each source category within the inventory area. An indicator is any parameter associated with the activity level of a source, such as production, employment, or population, that can be correlated with the air pollutant emission from that source.

In general, one of four factor-based emission estimation approaches is used to calculate area source emissions:

- Per-capita emission factors;
- Employment-related emission factors;
- Commodity consumption-related emission factors; or
- Level-of-activity-based emission factors.

A major portion of the work that goes into creating an area source inventory involves collecting information that defines the collective activity for the source category. Several methods are available for estimating area source activity levels and emissions:

- Treating area sources as point sources;
- Surveying local activity levels;
- Apportioning national or statewide activity totals to local inventory areas;
- Using per capita emission factors; or
- Using emissions-per-employee factors.

Source activity may fluctuate significantly on a seasonal basis. As area emissions are generally a direct function of source activity, seasonal changes in activity levels are examined closely. Emissions are calculated on a TPY basis and seasonally adjusted for peak ozone season daily emissions.

2.4.6.3 On-Road Mobile Source Emissions

On-road mobile source emissions are compiled once every three years for the Ozone SIP Emissions Inventory. Pollutants covered are VOCs, NO$_x$, and CO emitted by vehicles traveling on the Delaware highway system. The mobile source emissions inventory provides estimates of statewide emissions through the application of a network-based travel demand model. Two models of Delaware’s highway system are available: one represents New Castle County, and the other, Kent and Sussex counties. These travel demand models are updated to 1993. They are adaptable to estimating vehicle miles traveled (VMT) for various temporal and seasonal conditions, and they have an extensive capability for forecasting future year VMT based on changes in land use and in the transportation system. The model networks include federal highway functional classes and local collector roads.

The New Castle County (NCC) travel model estimates for 1993 were derived from the traditional four-step trip generation, trip distribution, modal split, and trip assignment process. The Kent and Sussex counties (KSC) model is similar to NCC except for the modal split component. The NCC and KSC models generate 24-hour volumes representative of average annual daily traffic (AADT). The models were modified to also produce morning and evening peak-period traffic data with travel speeds representative of these periods. Subtracting the total peak-period data from the 24-hour data generated the off-peak hour data (20 hours). Further adjustments were made to represent the typical ozone day. The traffic data were adjusted to August for New Castle and Kent counties and to July for Sussex County.

The emission factors were developed by the Department using MOBILE5A, which is the EPA’s most recent version of the computer model used to calculate VOCs, CO, and NO$_x$ vehicle emission factors. These emission factors take into account numerous parameters that affect vehicle emissions. Parameters include county-specific vehicle registration, age distribution, an inspection and maintenance program, ambient temperatures appropriate for the ozone season, gasoline Reid Vapor Pressure, operating mode, and vehicle speeds.

2.4.6.4 Off-Road Mobile Sources

Off-road mobile source inventories are compiled once every three years for the Ozone SIP Emissions Inventory. Pollutants covered are VOC, NO$_x$, and CO. Off-road mobile sources are not calculated with the same methods as on-road mobile source emissions. The off-road mobile source categories are aircraft, marine vessels, railroad locomotives, race cars, and other off-road sources. The other off-road sources category encompasses miscellaneous equipment such as construction equipment, farm equipment, industrial equipment, lawn and garden equipment, motorcycles, and recreational vehicles. All emissions are estimated on an annual basis (TPY) and on a peak ozone season daily basis (TPD).
2.4.7 ADDENDUM #2 – PROGRESS TOWARD ATTAINMENT OF THE NAAQS FOR OZONE

The 1990 Clean Air Act Amendments (CAAAs) contain provisions for the attainment and maintenance of the National Ambient Air Quality Standards (NAAQS). Control plans must be developed in designated non-attainment areas. Plan requirements vary depending on the severity of the individual area’s air pollution problem.

One key requirement of the CAAA for moderate and above ozone non-attainment areas involves achievement of Reasonable Further Progress (RFP) toward the attainment of the NAAQS. States must demonstrate RFP by achieving at least a 15 percent reduction of peak ozone season daily volatile organic compounds (VOC) emissions from 1990 levels by 1996. In addition, states must offset any net growth projected from 1990 to 1996. A nine percent reduction of VOC or NOx is required for every three years between 1997 and 2005. 2005 is the year in which, through the use of computer modeling, severe non-attainment areas must demonstrate attainment. Modeling results may indicate that reductions greater than the RFP reductions are required to achieve attainment of the ozone NAAQS.

Progress toward attainment of the NAAQS in the year 2005 is measured by periodic emission inventories conducted every three years, beginning in 1993. Actual air emission data are inventoried for reactive VOCs, oxides of nitrogen (NOx), and carbon monoxide (CO) from point, area, and mobile sources.

Point sources, as defined for the 1990 base year and successive inventories, are those facilities/plants/activities that have actual emissions greater than or equal to at least one of the following: 10 tons per year VOC, 100 tons per year NOx, or 100 tons per year CO. Detailed plant, point, and process data are maintained by each point source. Area sources represent collections of many small air pollutant emitters existing within a specified geographical area. Because area sources are too small and/or too numerous to be surveyed and characterized individually, area source emissions must be estimated collectively. Mobile sources are represented by all forms of transportation (commercial, recreational, and private), as well as portable machinery and tools powered by internal combustion engines. Emissions for mobile sources are estimated through primary data, computer modeling, and collective estimates.

In 1994, the Department submitted a 15 percent VOC reduction plan for 1996 to the EPA. The plan targeted reductions through multiple-control strategies, including gasoline vapor collection, low-volatility coatings and solvents, and controlling leaks in manufacturing processes. Additionally, a summertime ban on open burning is in effect, and further reductions in VOCs will be achieved by requiring the use of reformulated gasoline.

Delaware must produce three more rate-of-progress plans for target years 1999, 2002 and 2005 that ensure an additional 9 percent reduction in VOCs. In addition, a Year 2005 model attainment demonstration must be completed. Many new emission control strategies must be developed and implemented to attain the ozone standard by 2005.
2.5 WATER RESOURCES

2.5.1 INTRODUCTION

2.5.1.1 Background

Surface water is the water visible on the Earth’s surface. It covers nearly 70 percent of the Earth’s surface and includes oceans, lakes, rivers, streams, and wetlands. Surface water is critical to all life cycles; it houses resources, nutrients, minerals, and energy. It also provides a three-dimensional medium for flora and fauna.

Delaware has diverse surface-water resources, from faster-moving Piedmont streams to slow-moving coastal plain streams; the Delaware Bay and Inland Bays estuaries; and many tidal rivers containing fresh or brackish waters. Surface waters support uniquely diverse fish and wildlife populations, provide multiple recreational opportunities, and provide approximately 70 percent of the drinking-water supply for New Castle County.

The Chesapeake Basin generally consists of slow-moving coastal plain streams although the tidal Nanticoke River, the tidal Broad Creek, and the Chesapeake and Delaware Canal are exceptions.

2.5.1.2 Historical Perspective

The progress of mankind has taken its toll on surface-water quality. Recent improvements in environmental protection and awareness have helped, but pollution remains a major concern. As recently as 1975, Delaware routinely experienced serious water pollution and public health problems as a result of the discharge of untreated sewage and wastes. Since then, as a result of voluntary efforts, regulatory actions, and significant private and public investments in wastewater treatment facilities, localized improvements in water quality have been achieved.

The need for additional cleanup and pollution prevention continues. The focus of water-quality management has shifted from point source discharges (end-of-pipe) to decreased stream flows and nonpoint source problems, such as urban and agricultural runoff, erosion, and sedimentation. Unaddressed, these problems lead to poor habitat conditions for fish and other aquatic life, decreased enjoyment of our surface waters for recreation, and unhealthy conditions for those surface waters upon which we rely for drinking-water supply and other domestic uses.

As a result of water-quality protection programs that are in place in Delaware, surface-water quality has remained fairly stable in spite of increasing development and population growth. Impacts to waters are generally the result of past practices or contamination events, activities that are not regulated or otherwise managed,
or changes/events that occur on a larger regional scale. For example, air pollutants from sources outside of Delaware may contaminate Delaware’s surface waters via rainfall.

Improvements in water quality have been documented in localized areas where a discharge was eliminated or better treatment installed. Basin-wide water-quality improvements in waters that are being impacted by historical yet unquantified pollution sources are very difficult to detect over a short period of time. Targeted monitoring over long time periods (years) is necessary in order to detect changes.

Although Delaware’s surface-water quality may not have changed significantly over the last several years, there have been many improvements made in watershed assessment approaches and methodologies. Additionally, many water-quality criteria are stricter as a result of amendments to the state’s Water Quality Standards. Therefore, we have become more proficient at identifying water-quality problems and, at the same time, are calling for higher-quality waters.

The stability of Delaware’s surface-water quality is likely the result of increased efforts to control both point and nonpoint sources of pollution. In addition to the significant investments in wastewater treatment technologies previously mentioned, many private business interests are investing in practical and cost-effective nonpoint source pollution control practices (Best Management Practices) on farms, residential developments, and commercial and industrial sites. Likewise, public agencies such as the Delaware Department of Transportation are investing revenues in improved storm-water management practices and wetlands creation to mitigate the impacts of maintenance and new highway construction activities.

The detailed assessment that follows indicates water quality in the majority of the Basin remains stable, but cautions that phosphorus and bacteria levels are relatively high, causing concern for nutrient over-enrichment and potential health risks to swimmers. In addition, localized increasing nitrogen trends were identified in the Nanticoke, Marshyhope, and Chesapeake drainage watersheds.

### 2.5.2 SURFACE WATER

#### 2.5.2.1 Watershed Characteristics

The Chesapeake Basin has a long narrow drainage area in western Delaware (see Map 1.2-1 Chesapeake Basin Watersheds). The Basin includes seven watersheds: Elk Creek, Chesapeake Drainage System, Choptank River, Marshyhope Creek, Wicomico River, Pocomoke River, and the Nanticoke River and its tributaries (Broad Creek, Gum Branch, Deep Creek, Gravelly Branch). Part of the Chesapeake and Delaware Canal, from south of Lums Pond to the Delaware and Maryland State Line, is also included in the study. Drainage areas in New Castle County and Kent County are much of the headwaters. Following is a description of each watershed’s characteristics.

**Upper Chesapeake Bay Drainage System**

For the purpose of this portion of the assessment, the Elk River, Perch Creek, western segment of the Chesapeake and Delaware Canal, Bohemia River, Sassafras River, and the Chester River are referred to as the Upper Chesapeake Bay Drainage System. Minor portions of these watersheds are within Delaware and drain through Maryland’s eastern shore to the Chesapeake Bay. The area within the segment is rural and the topography is flat, ranging between 50 and 100 feet above sea level. There are numerous small streams throughout the watersheds. The residential development in this area is dependent upon individual septic systems. The area is principally farms, which are scattered throughout.

Pathogens (as indicated by elevated *Enterococcus* levels), nutrients, physical habitat condition, and water supply are the main concerns for this watershed.

**Choptank River Watershed**

The Choptank River watershed is located in the western-central portion of Kent County. It is bounded on the west by the Maryland State Line, on the southeast by the Marshyhope Creek and Murderkill River watersheds, on the northeast by the St. Jones River watershed, and on the north by the Chester River watershed. Land area in this watershed is approximately 61,000 acres. The Choptank River is 2.7 miles long within Delaware. It is formed by the confluence of Culbreth Marsh Ditch (10.7 miles long) and Tappahanna Ditch (10.6 miles long). Cow Marsh Creek (17.4 miles long) is another watercourse. Major tributaries that merge with the Choptank River in Maryland include Heron Run, White Marsh Branch, and Sonston Prong, which combine to form Gravelly Branch. The major tributary of Cow Marsh Creek is Meredith Branch. All streams generally flow in a westerly direction. There are no tidal areas located in this segment. The streams are rather slow and turbid. During dry periods, some segments are ephemeral. The watershed is level to gently sloping and is poorly drained.

Pathogens (as indicated by elevated *Enterococcus* levels), high bacteria counts, low dissolved oxygen levels, nutrients, physical habitat condition, and water supply are the main concerns for this watershed.

**Marshyhope Creek Watershed**

The Marshyhope Creek watershed is comprised of about 61,000 acres straddling the Kent and Sussex County borders near the Maryland State Line. The 15-mile long main stem of the creek rises west of Harrington and flows southwest into Maryland west of Bridgeville. Marshyhope Creek is a major tributary to the Nanticoke River Estuary.
in Maryland. The majority of land in this watershed is used for agricultural purposes, although forests cover a large area.

Pathogens (as indicated by elevated *Enterococcus* levels), high bacteria counts, low dissolved oxygen levels, nutrients, physical habitat condition, and water supply are the main concerns for this watershed.

**Upper Nanticoke River System**

The Upper Nanticoke River System (including the Gum Branch, Gravelly Branch, and Deep Creek watersheds) covers approximately 179,000 acres in western Sussex County. Generally, the topography of the area is flat to slightly undulating except for very short steep slopes along the major streams. Concentrations of population are not limited to the towns of the watershed, but extend along all highways connecting the towns. The rural non-farm population is rapidly expanding and is most noticeable in the areas of well-drained soils, particularly from Greenwood to Seaford. The major land use in this watershed is agriculture.

The waters of the Nanticoke River System are designated as having Exceptional Recreational or Ecological Significance (ERES) and, therefore, receive a higher level of protection. The watershed supports a variety of valued recreation opportunities including recreational and tournament fishing; boating, and water skiing; swimming; wildlife observation; and hunting. However, surface-water-quality data indicate stresses to the watershed including high nutrient loads, high bacteria counts, and occasional low dissolved oxygen levels.

Pathogens (as indicated by elevated *Enterococcus* levels), nutrients, physical habitat condition, and water supply are the main concerns for this watershed.

**Broad Creek Watershed**

The Broad Creek watershed is comprised of about 75,000 acres in southwestern Sussex County. The 20-mile long main watershed rises east of Delmar and flows toward the northwest through Trussum and Records ponds to the town of Laurel. The creek, which becomes tidal freshwater at this point, continues northwest to its confluence with the Nanticoke River southwest of Seaford. The major land use in the watershed is agriculture, although residential uses are important at Laurel. State-owned areas that provide access to water-based recreation include Horseys Pond, Records Pond, and Raccoon Pond.

The waters of the Basin are designated as having Exceptional Recreational or Ecological Significance (ERES) and, therefore, receive a higher level of protection. However, surface-water-quality data indicate stresses to the watershed, including high nutrient loads, high bacteria counts, and occasional low dissolved oxygen levels.

Pathogens (as indicated by elevated *Enterococcus* levels), nutrients, physical habitat condition, and water supply are the main concerns for this watershed.

**Pocomoke River Watershed**

The Pocomoke River watershed is comprised of roughly 16,000 acres in southern Sussex County. The 9-mile long main stem of the river in Delaware rises southwest of Millsboro and flows south to the Maryland border. The river eventually discharges to the lower Chesapeake Bay near Crisfield, Maryland. Basin land uses are split between agriculture and freshwater wetlands. Slopes are gentle.

Pathogens (as indicated by elevated *Enterococcus* levels), high bacteria counts, low dissolved oxygen levels, nutrients, physical habitat condition, and water supply are the main concerns in this watershed.

**Wicomico River Watershed**

At the time of this publication, there were insufficient data available to characterize this watershed.

### 2.5.2.2 Quality

The preliminary assessment of water-quality data for the Chesapeake Basin within Delaware has been done. The study used statistical methods to assess the chemical and physical water-quality data collected through the state’s ambient surface water-quality monitoring program.

The assessment analyzed data from 106 sampling locations distributed along the Nanticoke River and its tributaries, Choptank River, Marshyhope Creek, Upper Chesapeake Drainage System, and Pocomoke River (see Map 2.5-1 Surface Water Monitoring Locations). These data included general chemical and physical parameters, bacteria, and nutrients, and were retrieved mainly from the EPA’s STORET (STOrage and RETrieval) system. As these data had censored values, outliers, multiple observations within a time interval, as well as the common problems when data are retrieved and converted from one type to another type, they were manipulated and treated before applying statistical methods on them.

Mean, median, standard deviation, maximum, and minimum statistical parameters were used to characterize the existing condition. In addition, excursion analysis applied to parameters that had applicable numerical limits stated in the State of Delaware Surface Water Quality Standards or the EPA Quality Criteria for Water. Trend analysis was used to characterize the changes of the water-quality condition. It used the Mann-Kendall and Seasonal Kendall nonparametric methods. The analysis applied these methods to the data to test the statistical significance of apparent changes in concentration over time and, at the same time, estimated the magnitudes of the changes.
Results from the analysis showed major concerns related to the following parameters, as their concentration levels were frequently found above acceptable water-quality criteria limits:

- **Enterococcus** bacteria: Concentrations frequently exceeded the fresh-water-quality standard of 100#/100 ml in a number of places, mainly, along the tributaries.

- Total phosphorus: Excessive concentrations (average above 0.1 mg/l, 0.05 mg/l, or 0.025 mg/l) support the concern of nutrient enrichment in the Basin.

- Dissolved oxygen: Concentration exceeded the standard (5.5 mg/l for June to September and 4.0 mg/l as a minimum) quite frequently in the Broad Creek, Choptank River, Marshyhope Creek, and Upper Chesapeake Drainage System.

- pH: With the exception of values measured for the Chesapeake and Delaware Canal, pH values consistently fell outside the acceptable range of 6.5 standard unit – 8.5 standard unit.

Trend analysis showed that, collectively, no parameter had an obvious change throughout the Basin. Although there were instances where changes were detected at several locations, the magnitude and spatial coverage of the changes were not large enough to indicate significant change in water quality. Therefore, the study indicates that water quality in the Chesapeake Basin has remained stable.

**Eutrophication**

With increasing concerns over eutrophication in the Basin, several nutrient species have been analyzed for status and trend. They are described below.

**Phosphorus**

**Total Phosphorus.** Concern about phosphorus content in streams is based primarily on the role of phosphorus in promoting eutrophication. Among the major nutrients, phosphorus is most likely to limit plant growth in freshwater streams. This is the case in the Chesapeake Basin as manifested by nitrogen/phosphorus (N/P) ratio analysis discussed later in this part. Despite the strong correlation that exists between total phosphorus concentrations and the degree of eutrophication, a water-quality standard for phosphorus in streams has yet to be developed. However, the EPA’s “Quality Criteria for Water” suggests upper limits of total phosphorus for the prevention of nuisance growth. The criteria are 0.05 mg/l at the point where a stream enters a lake, 0.025 mg/l within a lake, and 0.1 mg/l in streams not flowing directly into lakes.

Excursion analysis of 1992–1996 records showed that total phosphorus exceeded the limits frequently (>25 percent of the time) throughout most of the Basin. The high exceedance suggests possible eutrophy existence in the Basin.

As discussed above, trend analysis suggests that total phosphorus has remained stable in the Basin. A few areas showed concentration changes, but the affected spatial coverage was too small to indicate a watershed-wide change in phosphorus level trends.

N/P ratios were calculated for each station to determine whether the limiting nutrient in the eutrophication process was phosphorus or nitrogen. Generally, a ratio above 10 indicates that phosphorus is the limiting nutrient, while a ratio below 10 indicates nitrogen as the limiting nutrient. N/P ratios throughout most the Basin were well above 10, thereby indicating that phosphorus is the limiting nutrient in the eutrophication process in the Basin. Only a few places in the Marshyhope Creek and the Upper Chesapeake Drainage System had N/P ratios of less than 10. **Map 2.5-2 Total Phosphorus Concentrations and Trends** shows the sampled locations and associated data.

**Nitrogen**

**Total Nitrogen.** Total nitrogen concentrations were calculated by adding up concentrations of Total Kjeldahl Nitrogen (TKN) and nitrate-nitrite nitrogen. Mean and median concentrations of total nitrogen were in the range of 1.13 mg/l – 6.72 mg/l. Trend analysis was not informative for this parameter.

**Total Kjeldahl Nitrogen (TKN).** Total Kjeldahl Nitrogen, which represents the combined concentrations of ammonia and organic nitrogen, is another water-quality indicator. A review of the current data showed that TKN concentrations were relatively uniform in the Basin. Between 1970 and 1996, decreasing trends were detected at several locations. Two locations, Tappahannix Ditch and Culbreath Marsh of Choptank River’s tributaries, had increasing trends with the changing rates of 0.168 mg/l and 0.195 mg/l, respectively.

**Nitrate-Nitrogen (NO$_3$ – N).** Nitrate-nitrogen and nitrite-nitrogen are the two highly bioavailable sources of nitrogen for phytoplankton growth. Generally, nitrate-nitrogen concentrations are much higher than nitrite-nitrogen, thus, contributing more to phytoplankton growth.

(Many stations did not provide separate measures of nitrate-nitrogen and nitrite-nitrogen, but, rather, combined the two. See the discussion on Nitrite-Nitrate Nitrogen.)

**Nitrite-Nitrogen (NO$_2$ – N).** See discussion in Nitrate-Nitrite Nitrogen.

**Nitrite-Nitrate Nitrogen (NO$_2$ + NO$_3$ - N).** Average concentrations of nitrite-nitrate nitrogen in the Basin ranged from 0.25 mg/l to 5.96 mg/l. Trend analysis showed that the following reaches had increases in nitrate-nitrite nitrogen concentrations:
1. Lower reach of Nanticoke mainstem near and downstream of Woodland Ferry;
2. Upper reach of Nanticoke main stem, from upstream of Seaford to northeast of Bridgeville;
3. Records Pond on Broad Creek;
4. Main stem of Marshyhope Creek near Adamsville; and
5. Gravelly Run of the Upper Chesapeake Drainage System.

These locations are shown on Map 2.5-3 Total Nitrogen Concentrations and Trends.

**Total Ammonia Nitrogen.** Ammonia nitrogen, which exists in waters as ammonia (NH₃) or as ammonium-ion (NH₄⁺), is an indicator of organic pollution. The ammonia (NH₃) form is toxic to fish, and toxicity varies with the pH of stream water. The EPA recommends 0.02 mg/l of NH₃ as a criterion to protect freshwater aquatic life.

Average concentration of ammonia nitrogen ranged from 0.019 mg/l to 0.563 mg/l. Decreasing trends were detected at several locations.

**Dissolved Oxygen (DO)**

Dissolved oxygen is the most essential measure of stream water quality. The Delaware Surface Water Quality Standards indicates that daily average concentration of DO should not be less than 5.5 mg/l in June – September, and minimum concentration of DO should not be less than 4.0 mg/l for supporting aquatic life.

Overall, DO levels were acceptable during 1992 – 1996. The mean and median concentrations of DO were generally above 5.5 mg/l. Excursion analysis showed water quality met the standards throughout most of the Basin. Only a few spots had data values that exceeded standards more than 25 percent of the time. During the same time, mean and/or median concentrations at these locations were below 5.5 mg/l. The occurrences of the exceedance were frequent enough to indicate that dissolved oxygen was not adequate to support aquatic life at these few locations. These locations were Trussum Pond and Raccoon Pond of the Broad Creek watershed; White Marsh Branch of the Choptank River; the upper stream of Marshyhope Creek; and Cypress Branch of the Upper Chesapeake Drainage System.

Trend analysis indicated that the concentrations of DO were quite stable in the Basin. The occasionally detected changes were not significant enough to suggest a Basin-wide change in level trends. Map 2.5-4 Dissolved Oxygen Concentrations and Trends shows the sampled locations.

**Chlorophyll-a**

Chlorophyll-a concentrations were high (>38 µg/l) along the lower reach of the Nanticoke main course from Sharptown up to Seaford, and in its tributaries of Hearns Pond and the lower reach of Broad Creek. No trend has been detected over time.

**Bacteria**

The state water-quality standard for primary contact recreation in fresh water is based on the geometric average of enterococcus bacteria. This average shall not exceed 100 colonies per 100 ml under conditions characterized by the absence of rainfall-induced runoff. As no such rainfall data were available along with water-quality data, the analyses were performed without considering the rainfall-induced situation. Primary contact recreation is the designated use for all streams in the Basin except for the Chesapeake and Delaware Canal.

Evaluation of historical data demonstrated that enterococcus bacteria concentrations violated the standard in a number of places. The following locations had geometric means that exceeded 100-colonies/100 ml:

A. Nanticoke River Watershed
   (1) Lower reach of Gum Branch;
   (2) Chapel Branch;
   (3) Clear Brook; and
   (4) Bucks Branch.

B. Broad Creek Watershed
   (1) Tussock Branch;
   (2) Meadow Branch;
   (3) Pepper Branch;
   (4) Saunders Branch;
   (5) Thompson Branch;
   (6) Elliot Pond Branch; and
   (7) Wiley’s Pond.

C. Choptank River Watershed
   (1) Culbreth Marsh;
   (2) Tappahanna Ditch; and
   (3) White Marsh Branch.

D. Marshyhope Creek Watershed
   (1) Main stem of Marshyhope Creek.

E. Upper Chesapeake Drainage System
   (1) Cypress Branch;
   (2) Sewell Branch; and
   (3) Gravelly Run.

Trend analysis indicated that concentrations of enterococcus bacteria in the Basin were remaining stable, except at two locations. Tappahanna Ditch and Culbreth Marsh of Choptank River’s tributaries had increase trends with rates 156 #/100 ml/year and 92 #/100 ml/year, respectively.

**Other**

**Total Suspended Solids**

Total suspended solids measures the impurities that may cause murkiness, turbidity, odor, color, and even disease. High solids content may also indicate high phosphorus concentrations that, in turn, promote eutrophic conditions.
Examination of historical data showed that total suspended solids concentrations in lower reaches of streams were three to four times higher than in upper reaches and their tributaries. In the Nanticoke watershed, the mean and median concentrations were around 20 mg/l in the lower reach of the main stem of the Nanticoke River (from Sharpstown Station 304011 up to Seaford Station 304031), while the mean and median were around 5 mg/l in the upper reach of the main stem (from Middleford Station 304041 to Northeast Bridgeville Station 304291) and the tributaries.

Overall concentrations were stable throughout the Basin. No significant changes were noticed in the main streams of the watersheds. Only two tributaries in the Choptank watershed had significant concentration increases: Culbreth Marsh with a rate of 7.0 mg/l/year, and Tappahanna Ditch with a rate of 5.8 mg/l/year.

**Total Hardness**

Total hardness is an important parameter for drinking water. Water supplies are classified as soft, moderately hard, hard, or very hard based on the following total hardness values:

<table>
<thead>
<tr>
<th>Total Hardness (as CaCO₃ in mg/l)</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 75</td>
<td>soft</td>
</tr>
<tr>
<td>75 – 150</td>
<td>moderately hard</td>
</tr>
<tr>
<td>150 – 300</td>
<td>hard</td>
</tr>
<tr>
<td>300 and up</td>
<td>very hard</td>
</tr>
</tbody>
</table>

Historical data showed that water in the Basin is soft. Total hardness concentrations were all below 75 mg/l, except one station at Summit Bridge on the Chesapeake and Delaware Canal, where total hardness had a mean 500 mg/l and median 264 mg/l. No significant trends were noticed in the Basin, except at Chesapeake City on the Chesapeake and Delaware Canal, which showed an increase of 40 mg/l/year.

**pH**

The state’s surface-water-quality standard requires that freshwater pHs be in the range of 6.5 to 8.5 standard unit (su). Although the mean and median were within this range for most of the Basin, the excursion analysis indicated that data points fell outside the range (below 6.5 su in most cases) quite frequently over wide areas of the Basin. Over time, no significant changes in pH trends (in water-quality perspective) have been identified.

**Water Temperature**

Water temperatures were relatively uniformly distributed throughout the Basin (i.e., around 13°C, but with noticeable variability between seasons). The lowest temperatures were 0°C recorded during the winter, while the highest was 31.5°C recorded in the summer. Over time, no changes have been identified for this trend.

**Total Alkalinity**

The Quality Criteria for Water has recommended 20 mg/l or more as CaCO₃ for freshwater aquatic life, except where natural concentrations are less. In the Basin, the mean and median concentrations of alkalinity were around 20 mg/l. Only a few places had lower concentrations of roughly 10 mg/l. These data indicate that Basin water has sufficient buffering capacity. No obvious change to this trend was observed over time for most of the Basin, although Sewell Branch in the Upper Chesapeake Drainage System had a decrease of 5.5 mg/l/yr.

**Biological Assessment of Nontidal Streams**

Biological and physical habitat data have been collected in Delaware since 1990 and have been used in the Section 305(b) reports in 1992, 1994, 1996, and 1998. These data are currently being compiled for the Chesapeake Basin Preliminary Assessment. The biological assessments are based upon aquatic macroinvertebrates, including the aquatic forms of insects, crayfish, worms, and snails. Physical habitat assessments are based upon visual measurements of the stream channel, banks, shade, and the riparian zone.

**Total Maximum Daily Load**

**Federal Clean Water Act Requirements**

Section 303(d) of the 1972 Federal Clean Water Act (CWA), as amended, requires states to develop a list of water bodies that need additional pollution reduction beyond that provided by the application of existing conventional controls. These waters are referred to as “Water Quality Limited” and must be periodically identified by the Department or the federal Environmental Protection Agency (EPA).

Water Quality Limited waters requiring the application of Total Maximum Daily Loads (TMDL) are identified in a document commonly referred to as the “303(d) list.” A TMDL is the level of pollution or pollutant load below which a water body will meet water-quality standards and thereby allow use goals such as drinking-water supply, swimming and fishing, or shellfish harvesting to be achieved. A state’s 303(d) list must be reviewed and approved by EPA by April 1st of every even-numbered year.

A full TMDL process determines the pollutants causing water-quality impairments, identifies maximum permissible loading capacities for the water body in question, and, for each relevant pollutant, assigns load allocations — Total Maximum Daily Loads — to each of the different sources, point and nonpoint, in the watershed.

The full TMDL process is an effective and important tool for achieving water-quality standards, but is time-consuming and labor-intensive. For this reason, TMDLs are currently pursued for high-priority waters with the
most severe water-quality problems including the Inland Bays, Nanticoke River, and the Appoquinimink River. These waters are typically impacted by both point sources (e.g., sewage treatment plants, industrial facilities) and nonpoint sources (e.g., storm-water runoff from urban and agricultural lands).

The CWA mandates that EPA perform all of the responsibilities not adequately addressed by a state. To date, scores of Section 303 lawsuits across the county have been filed against EPA. Plaintiffs have prevailed in most of those cases resulting in court-ordered TMDL development schedules as short as five years.

**Citizen Groups Sue EPA Over Delaware Water Quality**

In August 1996, James R. May, Esq., Director of the Environmental Law Clinic at Widener University School of Law, on behalf of the American Littoral Society (and its affiliate, Delaware River Keeper Network) and the Sierra Club, filed a federal complaint. This complaint charged the EPA with “the failure to perform its mandatory duties to identify and then to improve the water quality of hundreds of miles of rivers, streams, and Atlantic coastline, and thousands of acres of lakes, reservoirs, ponds, bays, estuaries, and wetlands in the State of Delaware which fail to meet the fishable and swimmable water-quality standard as required by the Federal Water Pollution Control Act, 33 U.S.C. §1251 et seq. (1988) commonly known as the Clean Water Act.” *(American Littoral Society, et al. v. United States Environmental Protection Agency, et al.; Civil Action No. 96-5920)*

The Complaint asks the Court to order EPA to:

- Comply with CWA requirements for TMDLs in Delaware on a short time line.
- Commit to updating Delaware’s Continuing Planning Process, which serves as the overall framework for water resources management in the state.
- Not issue or approve any new or renewed National Pollutant Discharge Elimination System (NPDES) permits discharging into impaired waters for which TMDLs or TMDTLs (Total Maximum Daily Temperature Loads) have not been established.
- Cease any additional grant funding to Delaware to administer the 303(d) program until the state’s 303(d) list meets the requirements of the CWA.
- Administer the NPDES program for Delaware until the state has an EPA-approved CPP in place.

The Department agreed to be present during a federally funded mediation process and assist EPA with program and technical issues. A settlement was reached and the Department’s Secretary and EPA’s Regional Administrator signed an interagency Memorandum of Understanding (MOU) dated July 25, 1997.

**Delaware’s Total Maximum Daily Load Program**

Since the early 1990s, EPA has urged states to adopt a watershed approach to water-quality management. EPA issued a new TMDL guidance document in 1991 encouraging the development of TMDLs on a watershed basis. Delaware has implemented a watershed approach that includes the integration of the TMDL monitoring and assessment program for each watershed in accordance with DNREC’s Whole Basin Management Program schedule.

**Settlement Negotiations.** Plaintiffs demanded an accelerated schedule to ensure that TMDLs for all 1996-listed waters will be established by 2006. DNREC and EPA agreed to a schedule for completion of the TMDLs on a 10-year schedule.

In included in the settlement with EPA, and in addition to the commitment to a 10-year schedule for TMDL development in Delaware, are commitments to prepare a supplement to Delaware’s 1996 List of Impaired Waters to include waters impacted by habitat degradation from agricultural and urban activities, develop guidance documents regarding the use of biological and habitat data for listing waters in 1998, and develop protocols for assessing wetlands in Delaware. The MOU between EPA and DNREC sets forth the duties of EPA and DNREC that will serve as the framework for administering the TMDL program in Delaware.

**Current TMDL Activities in the Chesapeake Bay Basin.**

The Nanticoke River and Broad Creek have been identified as water-quality-limited waters, included in Delaware’s 1996 and 1998 303(d) list, and were targeted for development of TMDLs by December 15, 1998. The major environmental problems in these waters are nutrient overenrichment and low dissolved oxygen levels caused by point source discharges and nonpoint sources.

By Secretary’s Order No. 98-W-0045, the Department has adopted the Total Maximum Daily Loads (TMDLs) Regulation for nitrogen and for phosphorus for the Nanticoke River and Broad Creek. The effective date of the final regulations was December 10, 1998, meeting the December 15, 1998 deadline.

**Future Pollution Management Activities.** Once a TMDL is promulgated, a Pollution Control Strategy (PCS) will be developed. A PCS will specify the necessary pollutant load reductions that need to occur such that loadings will be less than or equal to the TMDL. Plans are for reductions to be achieved through voluntary (for those activities that are voluntary now) and regulatory (for those activities that are regulated now) actions. However, TMDLs will provide watershed-wide pollution reduction targets which the Department (and EPA) will be legally obligated to meet. This obligation will require new approaches for addressing point and nonpoint sources of pollution. Concepts such as “pollution trading” between different sources of pollution, geographic targeting, and pollution prevention will all be considered as part of the PCS. Meeting these targets may require regulation under existing law.
2.5.2.3 Quantity

Streams in the Chesapeake Basin receive most of their water as base flow from ground water. This ground water, along with normal precipitation, provides an abundant water supply during all but the most severe droughts. However, localized water-quantity problems can arise if the resource is not properly managed. For instance, many of the small streams in the Basin are used as sources of irrigation water. As long as stream flow is normal or above, this use does not create a problem. If stream flow drops substantially below normal (due to over-utilization upstream or severe drought) then these small streams may suffer habitat degradation or loss, and the water is not available for other users downstream.

Stream-Flow Gauging

Eleven USGS stream-flow gauging stations are located in the Chesapeake Basin, two of which are still in operation (Table 2.5-1 USGS Stream Flow Gauging Stations and Map 2.5-1 Surface Water Monitoring Locations). The two active stations are Station 01487000 on the Nanticoke

<table>
<thead>
<tr>
<th>STATION ID</th>
<th>LOCATION</th>
<th>WATERSHED</th>
<th>DRAINAGE AREA (MILE²)</th>
<th>PERIOD OF RECORD</th>
<th>LATITUDE/LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>01487000</td>
<td>Nanticoke River, Near Bridgeville</td>
<td>Nanticoke</td>
<td>75.4</td>
<td>4/1/43-Present</td>
<td>38° 43' 45&quot; 075° 33' 41&quot;</td>
</tr>
<tr>
<td>01488500</td>
<td>Marshyhope Creek, Near Adamsville</td>
<td>Nanticoke</td>
<td>43.9</td>
<td>4/1/43-Present</td>
<td>38° 50' 59&quot; 075° 40' 24&quot;</td>
</tr>
<tr>
<td>01488000</td>
<td>Holly Dr., Near Laurel</td>
<td>Nanticoke</td>
<td>2.2</td>
<td>3/20/51-3/19/75</td>
<td>38° 32' 20&quot; 075° 33' 55&quot;</td>
</tr>
<tr>
<td>01487900</td>
<td>Meadow Branch, Near Delmar</td>
<td>Nanticoke</td>
<td>3.9</td>
<td>8/25/67-3/19/75</td>
<td>38° 29' 05&quot; 075° 35' 16&quot;</td>
</tr>
<tr>
<td>01486980</td>
<td>Toms Dam Branch, Near Greenwood</td>
<td>Nanticoke</td>
<td>6.4</td>
<td>5/21/66-3/19/75</td>
<td>38° 48' 04&quot; 075° 33' 28&quot;</td>
</tr>
<tr>
<td>01487500</td>
<td>Trap Pond Outlet, Near Laurel</td>
<td>Nanticoke</td>
<td>16.7</td>
<td>7/1/51-9/30/71</td>
<td>38° 31' 40&quot; 075° 28' 58&quot;</td>
</tr>
<tr>
<td>01488600</td>
<td>Marshyhope Creek, At Adamsville</td>
<td>Nanticoke</td>
<td>60.4</td>
<td>4/1/69-9/30/71</td>
<td>38° 49' 52&quot; 075° 41' 12&quot;</td>
</tr>
<tr>
<td>01490500</td>
<td>Culbreth Marsh Ditch, Near Chapeltown</td>
<td>Choptank</td>
<td>11.6</td>
<td>2/1/51-9/30/56</td>
<td>39° 04' 45&quot; 075° 41' 05&quot;</td>
</tr>
<tr>
<td>01490470</td>
<td>Tappahanna Ditch, Near Hartly</td>
<td>Choptank</td>
<td>5.9</td>
<td>11/08/51-2/3/73</td>
<td>39° 08' 07&quot; 075° 41' 04&quot;</td>
</tr>
<tr>
<td>01490490</td>
<td>Beachy Neidig Ditch, Near Willow Grove</td>
<td>Choptank</td>
<td>2.3</td>
<td>2/13/66-7/13/75</td>
<td>39° 04' 57&quot; 075° 39' 27&quot;</td>
</tr>
<tr>
<td>01490600</td>
<td>Meredith Branch, Near Sandtown</td>
<td>Choptank</td>
<td>8.4</td>
<td>2/13/66-7/13/75</td>
<td>39° 02' 23&quot; 075° 41' 52&quot;</td>
</tr>
<tr>
<td>01491010</td>
<td>Sangston Prong, Near Whiteleysburg</td>
<td>Choptank</td>
<td>1.9</td>
<td>9/21/66-7/13/75</td>
<td>38° 58' 25&quot; 075° 43' 32&quot;</td>
</tr>
</tbody>
</table>
River near Bridgeville, and Station 01488500 on the Marshyhope Creek near Adamsville. Figure 2.5-1 shows daily flows at Station 0148700 for the three-year period from 1992 through 1994. This figure shows that the yearly average flows at this station for the years 1992, 1993, and 1994 are 65.26 cubic feet per second (cfs), 88.62 cfs, and 133.49 cfs, respectively. Furthermore, the long-term average flow and the 7Q10 flow at this station are 90 cfs and 14.92 cfs, respectively. The 7Q10 flow is considered by water-quality managers as the critical low-flow condition for the stream, and represents the lowest seven-day average flow that occurs once in every ten years.

**Tidal Characteristic and Elevations**

The Nanticoke River, from its mouth at the Chesapeake Bay up to the Rd. 545 Bridge north of Seaford, and the Chesapeake and Delaware Canal are the only two tidal systems in the Chesapeake Basin.

Tidal characteristics of the Nanticoke River were studied during a three-year period from 1991 through 1994. This monitoring, conducted through a cooperative agreement between the Department and the USGS, was initiated to help develop a hydrodynamic and water-quality model of the Nanticoke River and its main tributary, Broad Creek. Figure 2.5-2 shows tidal elevation of the Nanticoke River at the Rte. 13 Bridge, near Seaford during the first five days of July 1992. The results of this and other similar studies indicate that within tidal portions of the Nanticoke River, average tidal range is about 2.5 feet, and maximum tidal velocity is less than 1.0 feet per second.

For the Chesapeake and Delaware Canal, the average tidal elevation at Summit Bridge is about 3.5 feet, and the maximum tidal velocity is roughly 2.0 feet per second.

**Stream Bathymetry**

The Department conducted a stream bathymetry survey of the Nanticoke River in 1991. During this survey, which was also coordinated with the USGS, cross-sectional profiles of the Nanticoke River at Sharptown, Maryland, and at Seaford, Delaware, were determined (see Figures 2.5-3a and 2.5-3b). The information gathered during this survey was used for developing and calibrating a hydrodynamic and water-quality model of the Nanticoke River and its main tributary, Broad Creek. The model development effort was completed in 1995.

### 2.5.3 GROUND WATER

Ground water is defined as the subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated. Ground-water studies, however, must include recognition of subsurface water found above the water table, termed the unsaturated (or vadose) zone, and of surface-water bodies. All three are tightly interrelated as part of the entire hydrologic cycle.

#### 2.5.3.1 Use

Ground water is both an important environmental and economic resource throughout the Chesapeake Basin because of its role in providing base flow to streams and wetlands (particularly important during times of low rainfall and drought), and as a source of water supply for domestic, public, industrial, and agricultural users. In all portions of the
Chesapeake Basin, ground water provides a vital supply of base flow to all streams and rivers. In the upper portion of the Chesapeake Basin, base flow contributes between 60 to 70 percent of the total stream flow (Baxter and Talley, 1997) and in the lower Chesapeake drainage to contribution is almost 80 percent (Johnston, 1976). Furthermore, except for the area above the Chesapeake and Delaware Canal, ground water is the sole source of drinking water and provides the majority of water for all other uses in the Chesapeake Basin.

2.5.3.2 Characteristics

As discussed in Section 2.1.2 (Geology), the entire Chesapeake Basin is in the Atlantic Coastal Plain physiographic province. Delaware's Coastal Plain is a layer cake of interbedded sand, silt, and clay that thickens as it dips to the southeast. The reader is directed to Section 2.1.2 for a more detailed description of the geology. This geology and the relatively high local precipitation of over 40 inches per year create an environment where ground water occurs at relatively shallow depths beneath the land surface throughout the Basin (see Map 2.5-5 Water Table Elevation). And, as detailed in the Geology Section, usable ground water can also be found at significant depths beneath the Basin.

The same factors that make the Chesapeake Basin's ground water easily accessible and plentiful can also lead to easier contamination from numerous land-use practices. Most of the soils in the Basin are very permeable, which enables the rapid transfer of surface contaminants into the unconfined (water table) aquifer. Map 2.5-6 Water Resource Protection Areas shows the extent of the areas with high ground-water recharge potential where rain and surface water can very rapidly enter the water table. In addition, many of the subsurface sediments are also quite permeable and can facilitate further migration of contaminants through the aquifer toward discharge locations (wells, streams, etc.).

For the purposes of ground-water-quality analysis, the resource must be further divided into unconfined and confined aquifers. In general, the unconfined, or water table, aquifer is more susceptible to anthropogenic contamination than are the deeper confined aquifers. This means that surface and near-surface land-use practices can more easily and more rapidly impact water quality in the unconfined aquifer. Contamination of the deeper aquifers is usually slower and, in most cases, is caused by localized, site-specific problems or practices. Although the water-table aquifer is more vulnerable to contamination, its accessibility, relatively high yield, and usable thickness make it the most highly utilized aquifer in the Basin for both potable and non-potable water. Sections 2.3.2 and 2.3.3 detail known and potential contaminant sources that can impact ground-water quality and, consequently, ground-water availability.

In this section, ground-water quality and quantity data are reviewed, and general conclusions about the resource are made. It is important to note that, in most cases, ground-water data by its very nature is a biased dataset. The water is extracted from wells that were often installed for specific purposes (domestic water use, contaminant monitoring, etc.) and is only a snapshot of the resource as a whole. Map 2.5-7 Ground-Water Monitoring Locations shows the locations from which the Department receives or collects ground-water-quality data. These data are collected for a number of purposes and represent the best currently available assemblage. The data and conclusions presented are, most often, well specific, and variables like well depth, aquifer, pumping rate, and well use should be understood before the data are used for other purposes.

2.5.3.3 Quality

Nutrients

As discussed in Section 2.3.2, many different land-use practices can introduce nutrients as a contaminant into the subsurface. The following is a brief summary of the nutrient-related findings associated with the data collection for this assessment.

Nitrate

Map 2.5-8 Nitrate Concentrations in Selected Wells shows the wells for which the Department has nitrate-nitrogen data. Because of resource constraints, most of this information comes from wells that were installed for reasons other than ambient water-quality measurements. The map ranks average nitrate concentration (as dot color) and shows the average and maximum concentrations along with the total number of samples for each well. These data come from numerous sources as indicated in the map legend.

An analysis of the map shows that nitrate levels near major towns are elevated when compared with levels observed for the same types of wells in the less developed portions of the Basin. The areas near Bridgeville, Laurel, and Seaford have the highest average and maximum concentrations. There are seven locations near Bridgeville (three Public Water Supply (PWS) wells, two Ground Water Discharge (GWD) Monitoring sites, and two United States Geological Survey (USGS) wells) and three locations near Laurel (two PWS wells, and one GWD site) with average concentrations exceeding the 10 mg/l maximum contaminant level (MCL) drinking water standard. This condition does not necessarily mean that consumers are drinking water that exceeds this standard, as water is often diluted to below these levels in the water supply systems.

Very little information is known about the average water quality of the numerous domestic wells in the more
rural areas throughout the Basin. Although Andres (1994) estimates that almost 20 percent of the population of southern Kent and Sussex counties have domestic well water with nitrate concentrations exceeding 10 mg/l, location-specific water quality is not well defined. During the 1993 National Water Quality Assessment (NAWQA) investigation, the USGS found average nitrate concentration to be 6.7 mg/l for wells in the Nanticoke watershed. Work done for the Department’s 1996 Watershed Assessment Report (305(b)) showed that the average nitrate concentrations for Public Water Supply wells in the Nanticoke watershed was 4.15 mg/l. These PWS wells are generally deeper than common domestic wells, and since nitrate concentrations, in general, decrease with depth, the potential for higher average concentration in shallow wells exists.

Lack of data for the middle and upper portions of the Basin is evident (refer to Map 2.5-8 Nitrate Concentrations in Selected Wells). This shortcoming is due to the relative bias of the various data sets to areas of greater development. Individual private wells are used in most of the upper Chesapeake Basin and all of the middle Chesapeake Basin. Because of this abundance of private wells and the lack of compliance-monitored sites, there is very little routine collected ground-water data in these regions. The lack of shallow well data from the more rural areas throughout the Basin is almost certainly biasing the data presentation by not showing the impacts of septic systems and agricultural practices on ground water in those areas.

Ground-water nitrate concentrations in the Chesapeake Basin demonstrate that much of the area has been impacted by human activity. Furthermore, the lack of data for much of the more rural areas does not mean that there is no concern, but rather shows the limitation of the Department’s ability to assess the ground water in those areas with existing resources. To get an idea of the potential impact, compare Map 2.5-8 Nitrate Concentrations in Selected Wells to Map 2.5-9 Domestic Well Densities to identify areas where there is significant ground-water use with little information about water quality. For instance, east of Seaford, northwest of Laurel, and much of Kent County west of Dover show relatively high domestic well densities in areas with little or no ground-water-quality data.

Further information is required to truly understand Basinwide nitrate contamination trends. The lack of water-quality data for large portions of the Basin shows the need to incorporate all possible water-quality analyses into our “ambient” monitoring network. More effort should be made by the various programs and agencies to cooperate on future data collection and distribution.

**Phosphorus**

There are very few locations in the Chesapeake Basin where phosphorus data have been collected for ground water. The reason for the lack of data is that most of the ground-water monitoring locations shown on Map 2.5-7 Ground-Water Monitoring Locations have not been sampled for phosphorus. Phosphorus is not regulated under the Safe Drinking Water Act and therefore is not a required analyte in the PWS wells. Furthermore, phosphorus is often bound in the soil matrix and is usually not a major concern in ground water. Much more work and monitoring needs to be done if more information is to be obtained on phosphorus levels in ground water.

**Chemicals**

Section 2.3.3 discusses the many different chemical sources that can introduce contaminants into the subsurface. This problem occurs as a result of spills, leaks, land use practices, and permitted discharges. The following is a brief summary of specific chemical-related findings associated with the data collection for this assessment.

**Chloride**

Map 2.5-10 Chloride Concentrations in Selected Wells shows wells for which the Department has chloride data. Chloride contamination comes primarily from three sources: road salt application, direct discharge, and natural salt-water intrusion. The first two sources are anthropogenic while the third is completely natural. However, natural salt-water intrusion can be exacerbated by human practices (e.g., dredging, channeling, over-pumped wells, etc.). Because of resource constraints, most of this information comes from wells that were installed for reasons other than ambient water-quality measurements. The map ranks average chloride concentration (as dot color) and shows the average and maximum concentrations along with the total number of samples for each well. These data come from numerous sources as indicated in the map legend.

A review of Map 2.5-10 Chloride Concentrations in Selected Wells shows that, even though the data are sparse, chlorides in ground water are not a major concern in the Basin. There are isolated areas where elevated chloride concentrations have been detected, but most of the data show levels near background. With the exception of the public well north of Middletown and the USGS well northwest of Greenwood, the other elevated chloride levels are located in monitoring wells at sites that discharge saline wastewater.

Although the wells do not adequately cover the entire Basin, a general conclusion can be made at this point. Average chloride concentrations did not exceed the secondary MCL at any of the sites.

The lack of data for the middle and upper portions of the Basin is obvious from the map. Again, this shortcoming is due to the relative bias of the various data sets to areas of greater development. Individual private wells are used in most of the upper Chesapeake Basin and all of...
the middle Chesapeake Basin. This fact, coupled with the lack of compliance monitored sites, leads to very little routinely collected ground-water data in these regions. The lack of shallow-well data from the more rural areas throughout the Basin may bias the data presentation by not showing impacts of septic systems and road salting on ground water in those areas.

Iron

*Map 2.5-11 Iron Concentrations in Selected Wells* shows the wells for which the Department has iron data. Iron contamination can come from human sources like salvage yards and industrial facilities, but is also a commonly occurring natural contaminant. As discussed in Section 2.1.2, many of Delaware’s aquifers have significant levels of iron in the formation and, therefore, in the water. Iron contamination is mainly an aesthetic concern with regard to taste and water color, but the EPA has also established a secondary MCL of 0.3 mg/l for human consumption. Because of resource constraints, most of this information comes from wells that were installed for reasons other than ambient water-quality measurements. The map ranks average iron concentration (as dot color) and shows the average and maximum concentrations along with the total number of samples for each well. These data come from numerous sources as indicated in the map legend.

*Map 2.5-11 Iron Concentrations in Selected Wells* shows that numerous wells in the Chesapeake Basin have average iron concentration in exceedance of the 0.3 mg/l secondary MCL. Samples were collected from USGS wells and 20 PWS wells. No shallow monitoring wells from the GWD Monitoring sites are sampled for iron. The water from the PWS wells may be diluted to levels below the drinking-water standard prior to consumption, but the Safe Drinking Water Act does not require water suppliers to do so.

Once again, the lack of data for the middle and upper portions of the Basin is obvious from the map, again due to relative bias of the various data sets to areas of greater development. Individual private wells are used in most of the upper Chesapeake Basin and all of the middle Chesapeake Basin. This fact, coupled with the lack of iron analysis at compliance monitored sites, leads to very little available ground-water data in these regions.

Pesticides

Because a large portion of Delaware is devoted to agriculture, there is a significant chance of agricultural chemicals and by-products entering the subsurface as contaminants. Fertilizers contribute vital nutrients to the state’s many crops, but, when not used wisely, can also contribute to groundwater pollution. In order to compete in the global economy, many of Delaware’s farmers also use pesticides (herbicides, insecticides, fungicides, etc.) for better crop management. Such use can lead to these compounds contaminating various resources, like ground water.

Currently, the Delaware Geological Survey (DGS) has established an ambient ground-water-monitoring network in southern New Castle County (*Pluses on Map 2.5-7 Ground-Water Monitoring Locations*). At the time of this assessment, the only pesticide MCL exceedance detected by this network in the Chesapeake Basin occurred at a well located southwest of Middletown (Baxter and Talley, 1997).

The Delaware Department of Agriculture (DDA) has developed a statewide pesticide-monitoring network to test for these chemicals in ground water. The network consists of over 100 shallow wells, selected somewhat randomly, throughout the state. *Map 2.5-7 Ground-Water Monitoring Locations* shows the approximate location of these wells in the Chesapeake Basin (green arrows). The DDA and DGS are currently working on a joint investigation to report their findings. Those data will be available once that report is released. Until the results of the DDA and DGS report are available further conclusions about overall pesticide concentrations are limited.

Ground-Water Quality Conclusions

Besides naturally occurring iron, nitrate is the main contaminant of concern in ground water throughout the Basin. Serious concerns for other contaminants may exist on a localized, site-specific basis. Overall, the Chesapeake Basin is impacted by elevated nitrate levels more than by any other contaminant.

2.5.3.4 Quantity

Well Density

Maps

A series of maps, generated for this assessment, depicts various categories of water-supply wells found throughout the Chesapeake Basin. Categories include Domestic (*Map 2.5-9 Domestic Well Densities*), Public (*Map 2.5-12 Public Water Supply Well Locations*), Industrial (*Map 2.5-13 Industrial Well Densities*), and Irrigation wells (*Map 2.5-14 Irrigation Well Densities*), and are based on well-permitting data. With the exception of *Map 2.5-12 Public Water Supply Well Locations*, which shows the exact well locations, each of the other categories of wells is depicted on separate maps as “densities” using a graduated chromatic-scale corresponding to numbers of wells of specific types existing within modified-grid area polygons. Some limited well attributes are included on the maps, such as the well counts for modified-grids, and DNREC well-permit identification numbers as depicted on the public well map.

A composite map (*Map 2.5-15 Combined Well Densities*) shows the above categories of wells, in addition to moni-
toring wells, in point-coverage format. Except for public wells and industrial wells that are used for potable purposes, the point-coverage well locations are not the exact locations. Rather, the locations are roughly evenly distributed within the modified-grid area. This method of geographic location was used in the absence of longitude and latitude data for those wells. However, the public wells are plotted using corrected Global Positioning System (GPS) longitude and latitude data to the Department’s accuracy standard for GIS, and have been referenced for correct identification and ownership.

The monitoring wells plotted on the composite map are also in roughly even distribution within modified-grids and were included to indicate locations where groundwater quality is under investigation. Typical monitoring well installations are for evaluating underground storage tanks, community wastewater disposal systems, landfills, and even Superfund sites. Thus, areas with monitoring wells could be indicators of potential sources of contamination to water supply wells. This assessment technique is very generic, and site-specific information must be obtained for an area of interest to determine the existence or extent of any contamination problems. Refer to section 2.3 for a discussion on the known and potential contaminant sources found within the Basin.

Completing the map series is a map representing groundwater usage as a maximum-daily withdrawal rate within each modified-grid (also in a graduated chromatic scale). This map is based on the “Maximum Daily Use” as estimated at the time the original well construction permit was applied for, and, therefore, does not represent actual usage (Map 2.5-16 Maximum Daily Ground-Water Use).

**Interpretation**

Some observations can be made on the occurrence and distribution of the various wells. As seen in the composite density map, most wells are concentrated in and around municipalities, corresponding to traditional development and land-use patterns. Throughout the Basin, domestic supply wells are, in general, fairly evenly distributed in the rural areas, with industrial wells located near and within towns. A divergence from this pattern is seen in the middle of the Chesapeake Basin (Choptank River Watershed) and in the upper Chesapeake Basin west of Dover, where there is a predominance of domestic wells. This area lacks central public water systems as well as any major industrial or irrigation activity. There is also a relatively high concentration of domestic wells east of Seaford, also reflecting suburbanization in the vicinity proximal to a city. Although public water is available in Seaford, it is apparent that public water service has not been extended to the east side of Route 13, and a proliferation of domestic wells has been the result.

Irrigation wells are generally associated with major farming operations, which widely employ irrigation systems, and to a lesser extent with privately-owned farms. It is evident that very intensive agricultural activity exists in the Nanticoke River, Deep Creek, Broad Creek, Gum Branch, and Gravelly Branch watersheds. The predominance of agricultural land use in these areas may result in most of the private and public wells being installed closer to more urban areas (as compared to the portion of the Basin west of Dover, where residential development is concentrated but much less dense).

Some clusters of monitoring wells can be easily connected to known ground-water contamination sites, such as the Sussex County Landfill southeast of Georgetown along Route 9. Other sites include the Dupont-Seafood nylon plant landfill, and the Harvey and Knotts landfill in the extreme northern end of the Basin along Old County Road.

Areas of large ground-water withdrawals (as shown on Map 2.5-16 Maximum Daily Ground-Water Use) correspond most closely with the presence of irrigation wells. There is less of a relationship between numbers of irrigation wells within a modified grid and the intensity of irrigation withdrawals, as only a minority of the areas with the highest number of irrigation wells also have the highest rate of usage. This relationship may indicate geologic variation that affects ground-water availability, as well as, other factors related to actual farming operations.

**Water Use**

Most ground water is produced from the unconfined aquifer system named the Columbia Group. The Columbia is comprised primarily of well-sorted, fine-to-medium grained quartz sand and gravel. All potable water is provided by ground water. In the middle portion of the Basin, some limited use of the minor sand units in the confined Miocene-age formations occurs for domestic and small public wells. Deeper aquifers in the northern part of the Basin are tapped by several large public wells.

The Columbia Group aquifer in the southern portion of the Basin is especially productive, with possible yields from individual wells in excess of 3 million gallons per day. High yields are indicated by the concentration of high withdrawals associated primarily with irrigation in the Seaford and Laurel areas. The Columbia Group aquifer is also the source for most public and domestic supply. Throughout the entire Basin, approximately 80 modified-grids have combined well yields of greater than 1 million gallons per day.

Again, the ground-water usage map is based on estimated rates of use at the time of well construction. Actual rates of water usage are known for all industrial and municipal suppliers, who are required to submit production reports as a condition of their water allocation permit. Usage data are available for all permitted systems.
Data are limited on actual production rates for the majority of irrigation systems in the Basin. Several irrigation systems in the Basin do, however, hold water allocation permits, and historical records for those systems show that irrigation withdrawals constitute the majority of water usage during the irrigation season. Also, water usage for agriculture varies widely from season to season, depending on weather and cropping patterns.

Based on historical records, there are numerous surface-water intakes of various capacities throughout the Basin. Surface water is often used for irrigation in many parts of the Basin. These facilities cannot be accurately mapped at this time due to data availability issues. While records exist for surface-water irrigation systems, they were created in the early 1980s and have only been sporadically updated since. Few of these systems have been issued water allocation permits. A single industrial surface-water diversion exists in the Basin, and that is located on the Nanticoke River at the DuPont Seaford plant. This water is used for once-through cooling at the power generating station with a permitted maximum withdrawal rate of 64 million gallons per day.

### 2.5.4 DATA GAPS AND RECOMMENDATIONS

1. Because of the nature of the sampled media, it is often quite difficult to adequately sample ground water to characterize overall water quality in a large area. However, many programs and agencies are already collecting water samples for various reasons. Therefore, a combined strategy needs to be developed to coordinate, at least within the Department, these various ground-water sampling efforts. This coordination may include programs paying for the analysis of “new” parameters in another programs’ wells, or merely developing a more efficient means of storing and exchanging ground-water-quality data. With the exception of the lower New Castle County monitoring network, all of the data used in this assessment were collected for other purposes. There is much useful data just within the Department, let alone other agencies that could help greatly with overall analysis.

2. Due to the large gap in reliable data for irrigation systems, a recommended step is to locate all operating irrigation wells and surface intakes via GPS, and compile updated information on the facilities including verification of identification numbers, and other essential attributes.

3. The location of all facilities with water allocations should be updated and a coverage created in the Department GIS similar to that created for public supply wells.

4. Analyze up-gradient well data from monitored sites to see if there are any regional trends in ground-water quality.

5. Determine more accurate base-flow loading for impacted streams; compare ground-water and surface-water data for interactions.

6. Delineation of all source-water protection areas, such as wellhead areas and excellent recharge potential area.

7. Establish wellhead protection ordinances, Best Management Practices, and/or regulations.

8. Identify intensive ground-water extractive use in areas that may have water availability issues.

9. Accurately define all sub-cropping aquifer areas to help protect the deeper portions of these aquifers.

10. Develop depth to ground-water maps for the entire state that highlight areas with an extremely shallow water table.


12. Refine regional ground-water flow data with information from all possible sites.

13. Determine ground-water system lag time in various sites throughout the state. This could be very helpful in establishing timetables to see results of Pollution Control Strategies.

14. Future recommendations may emerge on permitting irrigation systems on a priority basis for stressed watersheds in order to properly allocate and manage water resources.

### 2.5.5 REFERENCES


2.6 WETLANDS

2.6.1 INTRODUCTION

Wetlands represent areas where water is the dominant factor that structures the environment and associated plant and animal communities. These communities are transitional habitats that occur between upland and deep-water habitats, and are considered to be among the most productive ecosystems on Earth. They are characterized by fluctuating water tables, wet soils, and plants adapted to living in wet conditions.

In recent years, Delaware’s portion of the Chesapeake Basin has lost significant wetland acreage due to development and/or agricultural land conversion. Although the rate of wetland destruction has slowed in recent years, 54 percent of the wetlands in Delaware, of which the Basin is part, have nonetheless been lost since 1780 (Dahl, 1990). Population increase is expected to contribute to further wetland degradation in the foreseeable future. Therefore, implementation of timely preservation efforts is crucial to stem further losses of these ecologically important wetlands.

The ability of wetlands to retain harmful nutrients or to transform them to environmentally harmless forms is well known. In fact, this knowledge has spurred efforts in the scientific and regulatory community to preserve wetlands for the purpose of controlling nonpoint source pollution. Ignoring or trivializing wetland preservation efforts risks the peril of reducing drinking-water quality, fisheries habitat, and various recreational opportunities.

2.6.1.1 Definition

As defined under Section 404 of the Clean Water Act, wetlands are:

“Those areas that are inundated or saturated by surface, or ground water at a frequency and duration sufficient to support, and that under normal circumstance do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, bogs, and marshes, and similar areas.”

2.6.1.2 Wetland Attributes

The development of attributes unique to wetlands occurs through the interrelationship of hydrology, soils, and vegetation. Specific diagnostic characteristics for these three parameters must be exhibited in order to designate an area as a wetland.

Wetland Hydrology

The presence of water is the most important determinant in the structure and function of a wetland. Water related mechanisms such as ground-water discharge,
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surface-water runoff, flooding, and tides provide the driving force for creating and maintaining wetlands. These mechanisms affect the nature of soils, which, in combination with water, determine the types of plants and animals that live in a wetlands environment.

**Hydric Soils**

*Hydric Soils* are a key attribute for identifying wetlands. Hydric soils are defined as soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper soil zone (National Technical Committee for Hydric Soils, 1991). Under these saturated, anaerobic conditions, leaching of common soil constituents (such as iron and manganese) occurs. Visual observation of these depletions (i.e., grey or yellow stains to soil matrix by reducing conditions) and concentrations (i.e., red or black colors imparted to soil matrix by oxidative conditions), is made possible by water-table fluctuations.

A significant portion of the soils that are found in the Basin are poorly to very poorly drained. Many of these soils are associated with the floodplains of creeks and rivers. Based on recent efforts by GIS experts in the Department, hydric soils were estimated to comprise at least 48 percent of the Basin’s historical land base. It is not certain what percent of the land base is currently occupied by hydric soils. However, it is suspected that the percent would closely mirror the wetland acreage estimates derived from the completed Statewide Wetland Mapping Project (SWMP; see Section 2.6.6.4).

**Wetland Vegetation**

Hydrophytic or wetland vegetation is characterized by dense growths of vegetation adapted to existing hydrologic and soil conditions typical of wetland environments. Wetland plants are adapted to growing under the anaerobic or low-oxygen conditions that exist when soils are seasonally or continuously flooded. Wetland plants have adapted to such conditions by developing a variety of structural or physiological adaptations (e.g., stomata size; greater pore space in cortical tissues) that essentially mitigate the normally detrimental effects of reduced oxygen conditions.

2.6.2 NATIONAL WETLANDS INVENTORY AND THE STATEWIDE WETLAND MAPPING PROJECT

#### 2.6.2.1 Introduction

In response to the need to inventory and classify wetlands, the U.S. Fish and Wildlife Service, under the supervision of Cowardin and others (1979), developed a method to consistently classify various wetland types throughout the United States. The resultant “Classification of Wetlands and Deepwater Habitats of the United States” was a comprehensive classification of all aquatic and semi-aquatic ecosystems. The “Cowardin Classification System,” as it is commonly called, was first employed in the U.S. Fish and Wildlife Service’s National Wetlands Inventory (NWI) maps.

#### 2.6.2.2 Statewide Wetlands Mapping Project

The Cowardin classification scheme has subsequently been adopted for use in the Statewide Wetland Mapping Project. The SWMP is a collaborative project between DelDOT and the Department, and involves an interdisciplinary group of wetland scientists, mapping experts, and engineers. The goal of the SWMP is to improve and update existing wetland inventories and transportation resources. Hard copy and digital SWMP maps (see Map 2.6-1 Wetland Locations) are generated from this project. These maps or orthophotographs exhibit various wetland signatures in the form of hues, or darkness/lightness variations, characteristic of specific vegetative types or hydrologic regimes. These photointerpreted signatures, in conjunction with existing wetland inventories, soil survey information, QA/QC field verification data, and other ancillary data, are used to delineate wetland boundaries or polygons on the SWMP orthophotos (Pomato, 1994). The photointerpreted maps, like the NWI maps, utilize alphanumeric codes to convey information about specific wetlands.

The use of aerial color infrared digital orthophotography by the SWMP is a significant improvement over the less distinctive monochromatic NWI maps. The fact that a skilled photointerpreter can delineate and identify mapping units such as vegetative types (e.g., broad-leaved deciduous, broad-leaved evergreen, etc.) or hydrologic regimes (e.g., A, B, C, etc.) with greater precision and accuracy is one of the chief advantages of aerial color photography.
2.6.2.3 Cowardin Classification Scheme applied to NWI or SWMP

This classification scheme is based on a hierarchical approach to classifying wetland types that is analogous to classification of animal or plant species. In this scheme, wetlands are broadly classified into five systems: Marine, Estuarine, Riverine, Lacustrine, and Palustrine. Marine and Estuarine systems are found along coastal environments.

![Modified Cowardin Classification System for Delaware Wetlands](image)

**Figure 2.6-1**

MODIFIED COWARDIN CLASSIFICATION SYSTEM FOR DELAWARE WETLANDS

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>CLASS</th>
<th>Subclass</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>US-Unconsolidated Shore</td>
<td>1. Cobble-Gravel</td>
</tr>
<tr>
<td></td>
<td>EM-Emergent</td>
<td>1. Nonpersistent</td>
</tr>
<tr>
<td></td>
<td>SS-Scrub-Shrub</td>
<td>1. Needle-Leaved Deciduous</td>
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<tr>
<td></td>
<td>FO-FORESTED</td>
<td>1. Needle-Leaved Evergreen</td>
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<td></td>
<td>OW-Open Water</td>
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<tr>
<td></td>
<td>US-Unconsolidated Shore</td>
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<td></td>
<td>EM-Emergent</td>
<td>1. Nonpersistent</td>
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<tr>
<td></td>
<td>OW-Open Water</td>
<td></td>
</tr>
<tr>
<td>ESTUARINE</td>
<td>AB-Aquatic Bed</td>
<td>1. Algal 1. Coral</td>
</tr>
<tr>
<td></td>
<td>RF-Reef</td>
<td>1. Coral</td>
</tr>
<tr>
<td></td>
<td>OW-Open Water</td>
<td></td>
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<tr>
<td>INTERTIDAL</td>
<td>AB-Aquatic Bed</td>
<td>1. Algal 1. Coral</td>
</tr>
<tr>
<td></td>
<td>RF-Reef</td>
<td>1. Coral</td>
</tr>
<tr>
<td></td>
<td>OW-Open Water</td>
<td></td>
</tr>
</tbody>
</table>

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### Palustrine Subsystem
- **Class**: AB-Aquatic Bed
- **Class**: US-Unconsolidated Shore
- **Subclass**: 1. Cobble Gravel
- **Class**: EM-Emergent
- **Subclass**: 1. Nonpersistent
- **Class**: SS-Scrub-Shrub
- **Subclass**: 1. Needle-Leaved Deciduous
- **Class**: FO-FORESTED
- **Subclass**: 1. Needle-Leaved Evergreen
- **Class**: OW-Open Water

### Riverine Subsystem
- **Class**: AB-Aquatic Bed
- **Subclass**: 1. Bedrock 1. Cobble Gravel 1. Persistent
- **Class**: US-Unconsolidated Shore
- **Subclass**: 1. Cobble Gravel
- **Class**: EM-Emergent
- **Subclass**: 1. Nonpersistent
- **Class**: OW-Open Water

### Estuarine Subsystem
- **Class**: AB-Aquatic Bed
- **Subclass**: 1. Algal 1. Coral
- **Class**: RF-Reef
- **Subclass**: 1. Coral
- **Class**: OW-Open Water

### Intertidal Subsystem
- **Class**: AB-Aquatic Bed
- **Subclass**: 1. Algal 1. Coral
- **Class**: RF-Reef
- **Subclass**: 1. Coral
- **Class**: OW-Open Water
and are not typically found in Delaware’s portion of the Chesapeake Basin. The other three categories are freshwater wetland systems. Riverine systems are associated with rivers and streams, and are restricted to aquatic beds within channels and to fringes of nonpersistent emergent plants growing on riverbanks or in shallow water. Lacustrine systems are associated with freshwater lakes or deepwater habitats greater than 2 meters deep at low water and greater than 20 acres in size. Palustrine systems are also freshwater systems, but are differentiated from lacustrine systems on the basis of water depth and size. Wetland systems such as Palustrine, which means marshy, are wetland systems that describe specific wetland categories such as marshes, swamps, and bogs. Palustrine wetlands and water bodies are wetlands and water bodies that are less than 2 meters deep at low water, and smaller than 20 acres in size. They may be either non-tidal or tidal wetland systems.

As mentioned previously, the Cowardin Classification System uses a hierarchical approach to classifying and delineating wetland types. This system consists of an ordered series of numbers and letters (alphanumeric...
coding) that reflect specific characteristics of wetlands and deepwater habitats. This classification system begins with the most broadly defined concepts (e.g., Systems), and ends with very specific descriptive modifiers (see Figure 2.6-1 and Table 2.6-1).

The system is represented by the first letter in the alphanumeric code, and this letter is capitalized. Each system (except the Palustrine System) is divided into sub-systems based on major hydrologic, geomorphologic, chemical, and biological characteristics. Sub-systems are denoted as numeric characters following the system symbol. Sub-systems are divided into classes, which describe the general vegetative appearance in terms of vegetative life form, or the composition of the substrate (e.g., Forested, Scrub-shrub, etc.). Classes are denoted by upper-case letters (e.g., “Scrub-shrub” is “SS”). Classes are subdivided into subclasses, which describe specific vegetative or substrate types (e.g., Broad-Leaved Deciduous, Needle-Leaved Deciduous, or Bedrock, Rubble, etc.), and are designated by numeric modifiers specifically keyed to the vegetative or substrate type. Following the subclass is an upper-case letter denoting the hydrologic regime. Hydrologic regimes (e.g., temporarily flooded, seasonally saturated, etc.) are coded to specific hydrologic types on the basis of frequency and duration of flooding. Additional refinement of the classification scheme is provided by modifiers, which describe specific hydrologic, chemical, soil, human impact and/or other characteristic of a particular wetland (see Figure 2.6-1 and Table 2.6-1).

2.6.3 WETLAND VEGETATION AND PLANT COMMUNITIES

2.6.3.1 Introduction

Wetland plant community structure and composition are influenced by many factors, including climate, hydrology, water chemistry and human activities. Important physical factors include (1) location of the water table; (2) fluctuation of the water table; (3) soil type; (4) soil acidity; and (5) salinity. Biotic factors (i.e., plant competition, animal actions, and human activities) also play a role in structuring a community. Plant composition is often altered by channelization and drainage of wetlands. Generation of surface spoil piles and altered surface-water drainage patterns often gives some undesirable plant species (e.g., Phragmites) a competitive advantage.

2.6.3.2 Definition of a Hydrophyte

Hydrophyte is the technical term applied to plants adapted to wetland environments. The U.S. Fish and Wildlife Service defines a hydrophyte as “any plant growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content” (Cowardin et al., 1979).

2.6.3.3 Plant Indicator Status Categories

The U.S. Fish and Wildlife Service recognizes four types of hydrophytes:

1. Obligate — Obligate hydrophytes are plants that almost always (estimated probability >99 percent) occur in wetlands, but may occur (estimated probability <1 percent) in non-wetlands.
2. Facultative wet — Facultative wet plants (estimated probability >67 percent to 99 percent) in wetlands, but also occur (estimated probability of 1 percent to 33 percent) in non-wetlands.
3. Facultative — Facultative plants (estimated probability 33 percent to 66 percent) are as likely to grow in both wetlands or in non-wetlands.
4. Facultative upland — Facultative upland plants are sometimes (estimated probability of 1 percent to 33 percent) found in wetlands, but occur (estimated probability >67 percent to 99 percent) in non-wetlands.

Vegetation is considered hydrophytic when 50 percent of all vegetative strata (e.g., tree, shrub, vine, and herb), have an indicator status of facultative or wetter (Tiner, 1985).

2.6.4 UNIQUE OR THREATENED WETLANDS

Delaware’s portion of the Chesapeake Basin contains a number of unique and threatened wetland types. These unique or threatened wetland types in the Basin include bald cypress (Taxodium distichum), Atlantic white cedar (Chamaecyparis thyoides), and coastal plain ponds (i.e., Carolina bays/Delmarva bays). These communities are considered priorities for protection due to rare species that they often contain, their growth form, and/or their unusual geomorphic setting or geologic origin (McAvoy and Clancy, 1993). In recognition of this fact, the Department and the Delaware Natural Heritage Program identified, inventoried, and mapped these unique wetlands for purposes of regulatory protection and resource management. Those wetlands deemed most threatened or unique were classified as Category I wetlands, while wetlands considered less threatened or unique were assigned higher category numeric designations (i.e., Category II and III). For semantic reasons, the term “categories” has subsequently been changed to “types.” However, the numeric designations representing specific wetland types remain the same. Additional information on unique or threatened wetlands can be found in the living resources section of this document.

2.6.5 DISTRIBUTION OF WETLAND TYPES

2.6.5.1 Introduction

The presence of dense growths of plants adapted to the existing hydrologic, chemical, and soil conditions is
the most conspicuous characteristic of wetlands in the Chesapeake Basin. As mentioned previously, five major wetland systems are recognized: Marine, Estuarine, Riverine, Palustrine, and Lacustrine. All but the Marine system exist in Delaware’s portion of the Chesapeake Basin, and they comprise 100 percent of the total wetland acreage and approximately 25 percent of the Basin’s total land area.

2.6.5.2 Palustrine Wetlands

Palustrine wetlands (i.e., bottomland forests, swamps, and marshes) comprise the vast majority (>99 percent) of the freshwater wetlands found within Delaware’s portion of the Basin. These wetlands have the greatest floral diversity of any wetland system due to their exposure to the greatest range of moisture regimes (Tiner, 1985). Palustrine wetlands may be tidally influenced and may include riparian and headwater riparian areas.

Riparian Wetlands

Riparian wetland is a sub-category of Palustrine wetlands. These wetlands are immediately adjacent to streams, rivers, or other water bodies, but are most often associated with low-order streams. Riparian wetlands comprise approximately 5 percent of the total wetland base in the Basin. These wetlands are very important for enhancing both ecological and water-quality values because they maintain unbroken wildlife corridors to the floodplain area, and reduce sediment and nutrient loading downstream. Brinson (1993) recognized ecological and water-quality values provided by low-order streams. He found that riparian transport (non-channelized overland flow, or ground-water quick-flow following storms from upland to downstream) is more effective for nutrient and sediment removal than overbank flow from high-order floodplain systems. He also noted that, as floodplain width narrows as one moves upstream (i.e., decreasing stream order), there is an exponential increase in the length of floodplain affected. In other words, low-order riparian wetlands are affected proportionally more per unit length area by anthropogenic impacts than wetlands associated with higher-order streams. Most of the coastal plain streams in the Basin are dominated by riparian flow.

Headwater Riparian Wetlands and Marginally Wet Riparian Wetlands

Because of their initial connection to the floodplain system (1st order streams), headwater riparian wetlands are considered extremely important. According to the Conservation Design for Stormwater Management manual (1997), Delaware (including the Basin) has predominately 1st through 3rd order streams. The smallest first-order riparian areas, only 3 meters wide, make up roughly one-third of the total floodplain area for most of the watersheds in the state.

Brinson (1993) found that low-order streams, because of their large surface area, are more susceptible to adverse environmental impacts than higher-ordered floodplain environments. Therefore, protecting these smaller headwater riparian areas can aid in safeguarding the ecological integrity of the larger downstream floodplain systems.

The environmental integrity of headwater riparian wetlands is also often dependent on the surrounding upland environment. Upland forests provide additional water-quality benefits by trapping sediments and converting nutrients to biomass prior to discharge into riparian wetlands (i.e., reducing sediment and nutrient load into the adjacent riparian wetlands).

Protection of headwater riparian wetlands is of critical importance for maintaining the ecological integrity of the entire floodplain system. A lack of regulatory protection and recognition of their ecological importance has often allowed marginally wet headwater wetlands to be filled and/or developed. It is imperative to enact regulations and/or conservation practices to protect these lands. Conservation practices (e.g., riparian buffers, conservation easements both for farmlands and upland forests, etc.), either through regulatory or economic incentives, would significantly help to maintain a high-quality environment.

2.6.5.3 Estuarine Wetlands

Estuarine wetlands are systems associated with coastal salt or brackish waters. These areas extend upstream into coastal rivers to the point where salinity levels decline to negligible measurable levels [less than 0.5 parts per thousand (ppt)]. These wetland systems comprise less than 1 percent of the wetland base within the Basin.

2.6.5.4 Lacustrine Wetlands

Lacustrine wetlands are systems such as deepwater habitats associated with lakes, reservoirs, and deep ponds. These wetland systems comprise less than 1 percent of the wetland base within the Basin.

2.6.5.5 Riverine Wetlands

Riverine wetlands are systems that encompass freshwater rivers and their tributaries, including the freshwater tidal reaches of coastal rivers where salinity is less than 0.5 ppt. These wetland systems comprise less than 1 percent of the wetland base within the Basin.

2.6.6 WETLAND LOSSES AND TRENDS

2.6.6.1 Introduction

Delaware’s portion of the Chesapeake Basin is over 700 square miles and represents approximately 1 percent of the entire Chesapeake watershed. The Basin has lost a significant amount of wetlands acreage although the rate of loss has slowed with increased introduction of wetland
regulations. The following trend studies outline wetland losses and trends since the 1950's.

### 2.6.6.2 Wetlands Trend Study by Tiner (1982 – 1989)

According to Tiner and others (1994), wetlands occupied approximately 105,000 acres in Delaware’s portion of the Chesapeake Basin in 1989. This study also showed that, during the same time period, palustrine vegetated wetlands decreased by a net total of 2,921 acres (or by 3 percent between 1982 and 1989) (see Table 2.6-2).

Of the three most common wetland types found within the Basin (Palustrine Forested (PFO); Palustrine Scrub-Shrub; and Palustrine Emergent (PEM)), PEM wetlands suffered the greatest losses (see Table 2.6-2). No wetland loss figures were given for Estuarine, Lacustrine, or Riverine wetland systems in this report, presumably because these systems comprise an insignificant portion of the wetlands in the Basin (each less than 1 percent).

Delaware’s portion of the Chesapeake Basin also contains about 46 percent of all ditched wetlands in the entire Chesapeake watershed (Tiner et al., 1994). This figure is disproportional to the total area of the state, given that Delaware has only one percent of the entire Basin’s area. According to Tiner et al. (1994), this extensive network of ditches impairs, to some extent, the natural functions of wetlands. As a result, large acreages of wetlands have been lost or irrevocably impacted by channelization activities.

### 2.6.6.3 Wetland Trend Study by Dahl and Others (1997)

Wetland loss concerns prompted an additional study by the United States Fish and Wildlife Service (USFWS). The study entitled *Status and Trend of Wetlands in the Conterminous United States* by Dahl and others (1997), for the USFWS, is the most recent attempt by this agency to determine wetlands losses and trends. The study projected wetland losses by using a statistical sampling design, random sample plots combined with special mathematical techniques, and updated photointerpretation.

Although this technique projected wetland losses over wide geographic regions beyond the Chesapeake Basin, it provided a reasonable estimate of the wetlands losses in our region. The projected wetland loss for the northeastern physiographic stratum, which encompasses the Chesapeake Basin, was estimated to be 20 percent between 1985 and 1995 (Dahl et al., 1997). Most of the loss of wetlands estimated during this time period was due to conversion of wetlands for agricultural land use.

Wetland losses between the mid-1950s and the late 1970s were considerably greater than wetland losses that occurred between 1985 and 1995. According to Tiner (1987), approximately 21 percent of Delaware's inland vegetated wetlands and 6 percent of its coastal wetlands disappeared during the earlier time period. However, like the wetland loss figures presented from Dahl’s report, these wetland loss figures are for a somewhat larger geographic area (in this case, the entire State of Delaware). Nevertheless, these figures provide a reasonable estimation of wetland losses experienced in Delaware’s portion of the Chesapeake Basin.

### 2.6.6.4 Trend Study Utilizing Statewide Wetland Mapping Project Data

In an attempt to improve existing wetland inventories, the Statewide Wetland Mapping Project (SWMP) was initiated. Previously, the most comprehensive mapping effort undertaken in Delaware’s portion of the Chesapeake Basin had been the United States Department of the

<table>
<thead>
<tr>
<th>VEGETATED WETLAND TYPE</th>
<th>1982 ACRES</th>
<th>1989 ACRES</th>
<th>ACRES CHANGED TO OTHER VEG WETLANDS</th>
<th>ACRES GAINED FROM VEG WETLANDS</th>
<th>ACRES DESTROYED FROM OTHER AREAS</th>
<th>NET CHANGE</th>
<th>% PALUSTRINE WETLAND LOSS 1982 – 1989</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFO</td>
<td>92,205**</td>
<td>91,407**</td>
<td>2,268*</td>
<td>579*</td>
<td>1,109*</td>
<td>(-)2,798**</td>
<td>~3%</td>
</tr>
<tr>
<td>PSS</td>
<td>3,395*</td>
<td>5,580*</td>
<td>767*</td>
<td>2,452*</td>
<td>151*</td>
<td>111</td>
<td>(+1,645*)</td>
</tr>
<tr>
<td>PEM</td>
<td>3,963*</td>
<td>2,189*</td>
<td>624</td>
<td>627</td>
<td>1,947*</td>
<td>(-)1,774*</td>
<td></td>
</tr>
</tbody>
</table>

Adapted from Tiner (1994)

* Standard error is less than 50 percent of the estimate, but greater than 20 percent of the estimate.

** Standard error is 20 percent or less than the estimate.

Note: Estimates without an asterisk have higher standard errors.
Interior, Fish and Wildlife Service, National Wetland Inventory (NWI) Project. This nationwide project was conceived in 1974 to provide information on the location, characteristics, and extent of wetlands.

With the advent and availability of higher resolution aerial color infrared photography in 1992, the SWMP was able to more accurately distinguish and identify wetland areas previously missed during the earlier NWI Project. The recently completed report by Tiner and others (1999) utilized this improved aerial photography in conjunction with Departmental “groundtruthing,” to generate the data necessary to assess wetland losses between the 1981/2 – 1992 time period.

From this data, a loss of 722 acres of palustrine vegetated wetland was projected. Of this total, 608.7 acres (84 percent) of these losses were due to agriculture. Wetland destruction from pond construction, industrial development, residential development, commercial development and highway and road construction was 45.7 acres (6.3 percent). The remaining vegetated palustrine wetlands: herbaceous rangeland, transitional land, and riverine deepwater habitats had projected losses of 67.9 acres (9.4 percent).

During this same period, only 10 acres of new palustrine vegetated wetlands were reestablished. Therefore, a net loss of 712 acres of palustrine vegetated wetlands were assessed for the Basin.

In the Chesapeake Basin, both the lacustrine and riverine systems had minor wetland increases. These increases are not noteworthy since the palustrine wetland system occupies over 99% of the Basin’s acreage.

2.6.7 WETLANDS MITIGATION AND COMPENSATION

2.6.7.1 Introduction

Any significant construction project may negatively impact tidal and/or non-tidal wetlands. Today, such projects (and their impacts) usually require some level of permit approval that ensures compensation for wetland impacts. Generally, wetlands in non-tidal areas are regulated by the federal government (U.S. Army Corps of Engineers), while tidal areas are regulated by the Department. In some instances, wetlands compensation is required by one or both of these agencies as any project may impact jurisdictional wetlands in both tidal and non-tidal areas. Depending on the quality of the negatively impacted wetland, the requirements for replacement/compensation vary in both size and quality. Where compensation requirements overlap, the federal agency requirements usually take precedent.

Among wetlands resource managers, scientists, and the general public, wetlands “compensation” and wetlands “mitigation” are used synonymously to describe wetlands compensation. To clarify, wetland mitigation is the actual process which a person conducting a project must complete to reach the stage of compensation. The mitigation process involves investigating project alternatives for avoiding impacts, rectifying actual impact by repairing, reducing/minimizing impact, and compensating for unavoidable impacts. Traditionally, compensation has taken place at or near the site of impact (i.e., on-site) and involves replacement of the impacted wetlands with wetlands of similar type (i.e., in-kind). In some unavoidable circumstances, compensation must take place away from the site of impact.

2.6.7.2 Wetlands Compensation Goals

The original intent of wetlands compensation was to attempt to replace the impacted wetlands with one adjacent to it so that species of plants and animals would not be displaced, and wetland functions would not be completely lost. While in many cases this intent remains a viable option, wetlands scientists and resource managers have acknowledged that the on-site and in-kind type of replacement compensation is often not practical. Impracticalities of this option are often shown to outweigh the benefits of doing such. In most cases, the replacement wetland has to be a created wetland, and created wetlands generally have a lower success rate compared to restoring a previously converted wetland, or enhancing a wetland in need of improvement. It is much more difficult to create a wetland where one has not previously existed. The inability to maintain appropriate hydrologic regimes can be a problem, and replacing wetlands occupying specific niches is another. Developers are also wary of the cost of creating versus restoring a wetland. Consequently, “off-site” and even “out-of-kind” compensation projects are now an alternative that have become part of the mitigation decision-making process.

Increased flexibility in the wetland’s mitigation process has improved the success rate of compensation projects. In the past, the creation, restoration, and even the enhancement of wetlands had been a very inexact science. Through the evaluation of data derived from increased research and completed compensation projects, it has become apparent that the use of replacement wetlands to offset impacts is both viable and more stable. Continually evolving wetlands assessment methodologies, coupled with the identification of planning issues associated with wetlands compensation projects, have contributed to this realization. These planning issues include type of hydrologic source desired (i.e., ground water, surface water run-off, and/or overbank flow); presence/absence of an open water component; type of vegetation needed to develop the desired community type; and geology/soils investigation to determine whether existing substrates are conducive to wetland development.
In addition, the establishment of a more flexible mitigation and compensation process is what State of Delaware resource managers need to properly plan for to ensure conservation of water and wetlands resources. Certain watersheds need improvements whether they are for water quality, habitat, nutrient removal, or any other of the functions that wetlands can provide. Depending on the size of the compensation project, wetlands can be strategically placed to make improvements on either a sub-watershed or watershed level. A very large compensation project, or a wetland’s compensation bank, could provide an even greater mechanism to achieve these same goals.

### 2.6.7.3 Wetlands Compensation Banks

The purpose of wetlands compensation banks is to establish compensation “credits” for wetlands that have been negatively impacted. For example, wetlands in one area or region can be replaced by a created, restored, or enhanced wetland in another. The permit requirements and mitigation sequencing of the federal agencies would be best served by wetlands banks, and the reduction of wetlands impacts as part of the mitigation process results in a need for banks. Through the sequencing process, the result is usually lower amounts of required compensation. Instead of doing a multitude of small compensation projects, a bank can offer more value when the bank is strategically located in a watershed of need. Although there are projects with large impacts, the majority of projects impacting wetlands only require minor compensation.

The siting of wetlands banks can offer a wide range of wetland benefits (e.g., water purification and filtration, flood attenuation, ground-water recharge) and values (e.g., recreation, fish and wildlife habitat, education, aesthetics, uniqueness, and heritage) in comparison to smaller piece-meal wetlands compensation sites. Another advantage of wetlands banks is they can be constructed and functioning (both administratively and ecologically) in advance of project impacts, thereby reducing temporal losses, as well as reducing the risk of failure associated with individual wetlands compensation projects. With individual wetlands compensation sites, the created or restored wetlands are not fully functioning until well after the impact has occurred. In pre-planning these wetland banks, resource management and regulatory agencies can coordinate more effectively, and, through improved planning, provide more attention to meeting multiple ecological objectives. Permit timing is also reduced if compensation wetlands are available at a bank for a developer to use. In summary, establishment of wetland banks can more efficiently combine financial resources, planning expertise, and scientific expertise.

Monitoring of wetland banks may provide information to improve the probability of success for subsequent mitigation efforts. The required monitoring of banks is usually for a five-year period, with a maintenance requirement of much longer duration. This level of monitoring will ensure that the integrity of a wetland bank is maintained.

Wetlands banks have already become a landscape feature in some areas of Delaware. For the most part, the Delaware Department of Transportation has created banks to address impacts associated with roadwork. These banks have occurred mostly near the Route 1 corridor. There are many developers and consultants that have an interest in banking and have expressed their desire to develop banks. These “private sector” banks are in the planning stages and will probably be constructed within the next few years.

At this time, there are no wetlands banks in the Chesapeake Basin, nor are there any planned in the near future. The increase in development within the Basin will ultimately require a wetlands bank to compensate for wetlands impacts within the Basin. There have been small compensation projects within the Basin. These smaller wetlands compensation projects are almost exclusively associated with drainage/tax ditch projects.

### 2.6.8 CHANNELIZATION

#### 2.6.8.1 Historical Perspective and Need

Many areas of the nation have historically based land uses on an infrastructure of man-made drainage systems. Delaware is no exception, and it has community and private drainage systems that date back to the 1700s. In the 1700s, drainage of wetlands was considered necessary for several reasons (e.g., food was desperately needed for armies and war-ravaged countries, so farming of every available acre was necessary; wetland-related diseases seriously affected populations; timber harvests were essential, etc.). The extensive drainage patterns constructed in early times were extensions of natural drainage patterns into poorly drained upland flats. These channels were constructed to better manage soil and water resources, and for flood protection.

The average annual rainfall in Delaware usually exceeds plant needs and evaporation rates, creating excess water for extended periods. The result is drainage and flooding problems for agricultural areas, as well as towns, rural communities, forests, and transportation facilities.

Without proper drainage systems, soils become over-saturated, or have standing water on them. This situation precludes efficient farming operations, as farmers cannot get into their fields for timely agricultural operations. Adverse effects on crop production include (1) inability to prepare soils for planting; (2) delays beyond optimum planting dates; (3) inhibited plant growth due to excess water in the soil profile; and (4) restricted harvests and/or
the inability to harvest. In addition, crops impacted by flooding or poor drainage often under-utilize nutrients, thereby creating potential excess nutrient contamination problems in downstream areas. Approximately 48 percent of the soils in the Chesapeake Basin are poorly drained due to low permeable clay type subsoil.

Today, proper water management for optimizing farming operations has become even more vital due to increasingly complex and expensive equipment and inputs (such as fertilizers and chemicals). The existence of stable drainage systems plays a large role in determining the economic success of most farming operations within the Basin. In addition to farming concerns, many rural roads depend on proper drainage outlets to control flooding and to minimize upkeep and maximize longevity.

For urban communities, controlling surface water runoff is critical. Proper drainage in areas with residential and industrial development is essential for maximum utilization of related facilities. Basements, septic systems, streets, recreational areas, storm-water facilities, parking lots, schools, and businesses all depend on an effective drainage system for proper utilization. Numerous programs, some dating back to the 1700s, have been implemented to address drainage and flooding issues.

The development of a drainage infrastructure in Sussex County received a large boost in 1935 when the Levy Court was authorized to sell bonds for drainage improvements. Ditch company operations for care and maintenance were also turned over to the Levy Court. Additionally, significant assistance came in the 1930s and 1940s with the formation of the Works Progress Administration (WPA) and the Civilian Conservation Corps (CCC). A primary function of these two groups was to construct drainage channels. In 1944, the formation of Conservation Districts further addressed statewide drainage problems. These Districts, with help from the Soil Conservation Service, provided construction equipment, cost-sharing benefits, and technical assistance for survey and design. A significant effort in the reconstruction of drainage channels took place after Public Law 566, known as “The Watershed Protection and Flood Protection Act” was passed in 1954. Most of the tax ditches in the Nanticoke, Marshyhope, and Choptank watersheds were reconstructed as a result of this law and related funding.

Over 200 years of channel work has established a basic drainage system throughout the state. However, maintenance of these systems for most of this time was not formally addressed, and, at best, took place voluntarily. As a result, the condition of the channels has slowly deteriorated due to sediment accumulation and vegetation overgrowth in the channels, and obstruction caused by fallen trees.

2.6.8.2 Tax Ditch Organizations

The Delaware General Assembly enacted the 1951 Delaware Drainage Law to establish ditch companies and to resolve related financial and maintenance issues. As an outgrowth of this law, the Division of Soil and Water Conservation (the Division) is mandated to carry out a comprehensive drainage program through Title 7, Chapter 41 of the Delaware Code — Drainage of Lands: Tax Ditches.

A tax ditch is a governmental subdivision of the state. It is a watershed-based organization formed by a prescribed legal process in Superior Court. The organization is comprised of all landowners (also referred to as taxables) of a particular watershed or sub-watershed.

Formation of a tax ditch can only be initiated by landowners who petition Superior Court to resolve drainage or flood protection concerns. Governmental agencies do not initiate the formation process. This petition action results in the Conservation District requesting an investigation by the Division to “determine whether the formation of the tax ditch is practicable and feasible, and is in the interest of the public health, safety and welfare.” If so determined, the Conservation District files the petition in Superior Court, and a Board of Ditch Commissioners (as directed by the resident judge) prepares a report on the proposed tax ditch. This report contains all required information per Title 7, Chapter 41, and is the basis for a hearing held for the affected landowners. At the conclusion of the hearing, a referendum is held for the landowners to approve or disprove formation of the tax ditch. The Board of Ditch Commissioners files the results of the hearing and referendum in Superior Court, and the Court holds a final hearing for any person to object to the formation of the tax ditch. Following the outcome of the final hearing, and if deemed appropriate, the Superior Court judge issues a Court Order establishing the tax ditch organization. The Court Order grants permanent rights-of-way to the tax ditch organization for construction and maintenance operations. It also empowers the organization with taxation authority to collect, from all affected landowners, funds to perform this construction and maintenance. Taxation amounts (ditch assessment base) for individual properties are also established through the Court Order.

Ditch managers and a secretary/treasurer oversee the operations of a tax ditch. These officers are landowners within the watershed and are elected at an annual meeting by the taxables.

To date, 228 individual tax ditch organizations have been formed throughout the state. These organizations range in size from the 56,000 acre Marshyhope Creek Tax Ditch to a 2-acre system in suburban Wilmington. These organizations manage over 2,000 miles of channels and provide direct or indirect benefits to approximately 100,000 people and almost one-half of the state-maintained roads. Map 2.6.2 Drainage Ditch Areas shows the extent of these organizations in the Chesapeake Basin.

Tax ditch channels range in size from approximately 6 to 80 feet wide, and 2 to 14 feet deep. Size variation is
due to the number of acres that drain to a particular site, and the topography of the area. For example, channels constructed through higher areas will be deeper than those going through lower areas. Generally, the more acres served by a channel, the wider it will be. In addition, the bottom “grade” of a channel and the degree of drainage required in an area will necessitate fluctuations in size.

Although tax ditches directly resolve many drainage and flooding problems, their primary purpose is to establish channel outlets for drainage and flood protection. From these channel outlets, individual landowners can construct private channels for use in management of their lands and for implementing various Best Management Practices for conservation.

Dependable drainage and flood protection in the Chesapeake Basin is essential for the management of many resources. Approximately 65 percent of the tax ditch organizations within the state are located in the Basin. Within the Basin, there are currently 148 tax ditch organizations containing approximately 1,528 miles of rights-of-way established for tax ditch management. These channels provide drainage and flood protection for approximately 298,650 acres, or 66 percent of the Basin area. It is estimated that an additional 1,200 miles of private channels exist throughout the Basin.

Tax ditches within the Chesapeake Basin have been organized and constructed utilizing the 1951 Delaware Drainage Law. These organizations are locally managed, with most following federally mandated operations and maintenance plans. The age of these organizations varies from 47 years old to the most recent, which is 3 years old. The older organizations have undergone routine vegetative maintenance and sediment dip-outs. The newer ones are now entering this phase. The condition of most of these channels is very good, although a few isolated organizations have not received adequate maintenance. In most of these isolated cases, negligence was/is mainly due to original landowners dying, and the influx of new landowners to the area. In most cases, these new landowners are simply unaware of the negative impact of a failing drainage system.

Currently, there are only a few areas within the Basin where landowners have petitioned for the formation of a new tax ditch organization. Many (approximately 20 – 30) areas have been investigated to solve small individual drainage problems. These smaller problems will probably be resolved through the public ditch program.

The breakdown of tax ditch data within the Chesapeake Basin on a county level is indicated in the chart above. In addition to tax ditch requests, the Division’s Drainage Section also responds to requests (mostly from legislators) for public ditches. Public ditches are generally smaller drainage systems that involve only a few mutually cooperative landowners. In the case of public ditches, landowners voluntarily grant temporary construction easements, usually to a Conservation District or a town/city. There are no provisions for perpetual maintenance by an organized group. The public ditches are planned utilizing the same BMPs used for tax ditches, constructed, and then left to the individual landowner’s responsibility for future maintenance. Many isolated drainage problems have been resolved in the Chesapeake Basin utilizing this one-shot approach.

### 2.6.8.3 Environmental Concerns and Mitigation

The Division’s Drainage Section is responsible for the formation, construction, and maintenance of Group Drainage Associations’ tax ditches and public ditches. Historically, the planning and construction of water management systems has been accomplished with only administrative considerations from governmental agencies. The traditional program was a single-purpose program (namely, drainage). Little consideration was given to environmental issues such as habitat or wetlands. As Delaware addressed clearly evident environmental concerns related to industrial and municipal discharge, development, and other areas, the environmental focus eventually progressed beyond these areas to other activities now recognized as also having potentially “significant environmental impacts.” Drainage of lands through tax ditches is one such activity.

Various environmental groups and regulatory agencies began to question the potential impacts these projects were having on natural resources. For example, interpretation of the Army Corps of Engineers and state wetland regulations became a frequent, ongoing process used by groups in an attempt to halt or minimize projects. Regulatory exemption requirements for channel construction were tightened, and wetland/habitat mitigation was more frequently required.

Changes in the water management program were initiated in response to these environmental concerns and issues. Additionally, Governor Castle’s Executive Order No. 56 mandated state agencies to achieve projects with a no net loss of wetlands. It is now recognized that natural resource impacts resulting from the reconstruction of drainage systems can and should be minimized. Weighing wetland concerns against drainage benefits prior to reconstruction of deteriorated channels has resulted in changes in procedures for selecting which channels to work on and what methods to use. For the past 10 years, numerous
governmental agencies have performed a rigorous review process out of which comments are incorporated into related project plans. Ideally, these extensive reviews ensure that environmental impacts are minimized, or at least compensated for when deemed unavoidable. Implementation of this process over the last 10 years has resulted in development of a detailed list of proven environmental practices that minimize impacts. This list has evolved into the Delaware Tax Ditch Best Management Practices (BMPs). Resource managers and planners on all water management projects routinely employ the BMPs. Some of the more significant practices include the following:

1. Minimize clearing widths;
2. Relocate channels around sensitive areas;
3. Perform only one-sided construction;
4. Save trees within construction zone;
5. Minimize construction of downstream outlets;
6. Install berm along wetlands with side inlet pipes at or above biological benchmarks; and
7. Block off old channels that drain only wetland areas.

To complement this effort, the Drainage Section has held wetland/environmental training sessions for both technical and administrative staff members.

The most significant environmental impact from channel construction is the fill and drainage of forested wetlands. Fill results from clearing operations and disposal of excavated materials. Drainage occurs when wetland areas are not protected from surface flow into the channel. Loss or alteration of these wetlands is compensated through the creation or restoration of freshwater wetlands, usually in marginal agricultural fields. During the past 10 years, adherence to planning principles, policies, and conservation management practices has minimized environmental impacts and provided long-term economic and environmental stability.

The Drainage Section has also carried out several projects to test new construction techniques and established demonstration/education sites. Most of the channel construction techniques emphasize minimal clearing and spoil disposal. The demonstration/education sites incorporate these new construction techniques with wetland restoration in adjacent agricultural fields. Three such project demonstrations have been performed in the Chesapeake Basin and have effectively shown that drainage and environmental quality do not have to be mutually exclusive. In addition, drainage channels essentially link upland farms, cities, industrial sites, etc., to receiving bodies of water. Although channels themselves produce very little nutrients or sediment, they do represent the primary transport mechanism for these parameters.

Sediment load in drainage channels usually represents a short-term problem that occurs during reconstruction or maintenance events. Once stabilized, within six months to one year after such an event, channels discharge minimal amounts of sediment and actually act as sediment traps as vegetative growth eventually covers the channel bottoms and side slopes. These short-term sediment load problems can be lessened if sediment traps and water-control structures are added. Such practices slow water flow and provide areas for sedimentation and nutrient uptake by plants.

However, when water-control structures are used, a concern exists that phosphorus tied to the sediment trapped upstream of these structures may be re-suspended through saturation. Current studies by Delaware State University on this potential problem are nearing conclusion.

Resolution of nutrient problems within the Basin will hinge on controlling and managing the source of these nutrients through effective use of BMPs for land management in cities, agricultural fields, rural areas, and industrial sites. For drainage channels themselves, increased usage of current and new BMPs for tax ditch construction and maintenance will assist in reducing sediments delivered by drainage channels.

Once tax ditch channels are constructed, maintenance is the primary function of each individual tax ditch organization. Maintenance consists of the routine control of vegetation within the rights-of-way and the periodic removal of accumulated sediment in the channel bottom. Control of woody vegetation adjacent to and within the channel is needed to retain access to the channel for future dip-outs of sediment. Rotary mowers and boom arm mowers have replaced traditional hand labor, utilizing tools such as bush axes. Unfortunately, mowing machines are not selective, and cut all vegetation, including shrubs and grasses that are desirable for wildlife habitat. Mowing is generally performed every other year on established channels.

The Drainage Section and Conservation Districts continually search for viable alternative methods for maintenance. Several attempts have been made to establish vegetative maintenance programs utilizing herbicide application. This method, which decreases maintenance frequency and promotes growth of desirable species, has had varying degrees of success and acceptance by the tax ditch community. Recent experimental attempts include the use of a “weed wiper bar.” This machine applies herbicides to targeted species by a wiping bar and leaves most desirable species untouched.

An alternative to controlling vegetation along rights-of-way for dip-out purposes is to allow trees to fully grow in the channel and along the accessway. This alternative presents a serious access problem every 15–20 years, when sediment needs to be removed. The channel and accessway would have to be stripped of this large vegetation, with resultant significant soil disturbance and erosion. By contrast, maintaining vegetation at desired levels...
(i.e., at heights/densities where dip-outs can readily be performed) is a more preferred method, as minimal channel-bank disturbance occurs during dip-out. As practicable alternative techniques for maintenance are developed, they are slowly incorporated into tax ditch maintenance plans through educational and promotional efforts.

In pursuing further innovations, the Drainage Section has become increasingly involved in David Rosgen’s “Geomorphic” approach to streambank restoration and channelization. Geomorphic design concepts are based on the evaluation of local/regional streams to measure natural characteristics that promote channel stabilization. Where applicable, these natural characteristics are integrated into tax ditch channel designs. A demonstration project utilizing these concepts has been implemented as part of the Pratt Farm Water Management project. In this project, a floodplain and sinuous low-flow channel were constructed in a marginal agricultural field to replace the historic straight channel. This Geomorphic approach will require special conditions and very receptive landowners to be successful. The Drainage Section will continue to develop data for use in this initiative as opportunities arise.

2.6.9 REGULATORY PROGRAMS FOR PROTECTION OF AQUATIC AND WETLAND RESOURCES

There are several federal and state level laws designed to protect the water resources and wetlands of Delaware. The most significant statutes at the federal level include the Rivers and Harbors Act of 1899 and the Clean Water Act of 1972. The most significant state laws are the Wetlands Act of 1973 and the Subaqueous Lands Act of 1969. The United States Army Corps of Engineers administers the federal laws. The Wetlands and Subaqueous Lands Section of the Department’s Division of Water Resources administers the state laws. Although there are some jurisdictional differences between the federal and state programs, the Corps of Engineers and the Wetlands and Subaqueous Lands Section coordinate their programs to minimize overlapping authority. Additionally, the Wetlands and Subaqueous Lands Section has assumed authority for certain jurisdictional functions formally handled by the Corps of Engineers. Both agencies have developed expedited procedures for reviewing projects under their jurisdiction.

2.6.9.1 Rivers and Harbors Act of 1899

The Rivers and Harbors Act of 1899 regulates activities in navigable waters of the United States. Navigable waters are defined in Delaware as all tidal waters and their tributaries to the head of the tide. In tidal waters, the shore boundary extends to the mean high-water line. In non-tidal waters, the shore boundary extends to the ordinary high-water line.

The law applies to any dredging or disposal of dredged materials, excavation, filling, rechannelization, or other modifications of a navigable water. The law also applies to construction of structures, including but not limited to, docks, piers, jetties, groins, weirs, breakwaters, shoreline protection (e.g., rip-rap revetments or bulkheads), piling, aerial or subaqueous utility crossings, intake or outfall pipes, boat ramps, or navigational aids.

2.6.9.2 The Clean Water Act

Section 404 of the Clean Water Act requires authorization from the Army Corps of Engineers for the discharge of dredged or fill material to go into waters of the United States, including wetlands. This Act applies to navigable waters, their tributaries, intermittent streams, lakes, ponds and wetlands. The criteria for determining whether an area is a wetland subject to Corps jurisdiction is contained in the Corps of Engineers Wetlands Delineation Manual. The criteria are based on specific vegetation, soil and hydrology characteristics (Environmental Laboratory, 1987).

Permits also are required for temporary fill projects such as temporary fills for access roads, cofferdams, storage and work areas, or dewatering of dredged material prior to final disposal.

2.6.9.3 Federal Permitting Requirements

Permits issued by the Corps of Engineers pursuant to the requirements of the Rivers and Harbors Act and the Clean Water Act are designed to ensure that this nation’s water resources are safeguarded and used in the best interest of the people. Environmental, social, and economic concerns are weighed as part of the permit application process. The Corps makes its decision about whether to issue a permit after a thorough analysis of a proposed activity’s probable impacts, including its cumulative impact on the public. Numerous factors, including general environmental concerns and existence of wetlands, are taken into consideration. Permits are generally issued unless the Corps of Engineers determines the proposed activity is not in the public interest.

To expedite the permitting process, the Corps of Engineers developed a system of nationwide and general permits designed to reduce the paperwork and time necessary to obtain an individual permit. Nationwide permits allow numerous pre-authorized activities. Activities include bank stabilization, road and utility crossings in wetlands, minor filling of wetlands, filling of headwaters, construction of boat ramps, and placement of mooring buoys. All such activities are conducted under certain pre-authorized conditions mandated by the Corps of Engineers.

General permits are designed to expedite the permitting process for certain structures in navigable waters.
These permits are also designed to meet criteria specific to the state in which they are issued. General permits are issued by the Wetlands and Subaqueous Lands Section.

2.6.9.4 The Wetlands Act

Tidal wetlands in Delaware are protected under the Tidal Wetlands Act of 1973 (7 Del. Code, Chapter 66). The act and the regulations written pursuant to the law regulate activities in tidal wetlands. Tidal wetlands are defined as:

“Those lands above the mean low water elevation including any bank, marsh, swamp, meadow, flat or other low land subject to tidal action in the state along the Delaware Bay and Delaware River, Indian River Bay, Rehoboth Bay, Little and Big Assawoman Bays, the coastal inland waterways, or along any inlet, estuary or tributary waterway or any portion thereof, including those areas which are now or in this century have been connected to tidal waters, whose surface is at or below an elevation of 2 feet above local mean high water, and upon which may grow or is capable of growing any but not necessarily all of the following plants: [list of plants] and those lands not currently used for agricultural purposes containing 400 acres or more of contiguous nontidal swamp, bog, muck or marsh exclusive of narrow stream valleys where fresh water stands most, if not all, of the time due to high water table, which contribute significantly to ground-water recharge, and which would require intensive artificial drainage using equipment such as pumping stations, drainfields or ditches for the production of agricultural crops.”

Tidal wetlands meeting this definition have been delineated on maps available from the Department. These maps are for public use to determine whether an area is a tidal wetland. The law states that a permit is required for any activity conducted in a tidal wetland. Activities include dredging, draining, filling, or bulkheading. They also include construction of any kind, including but not limited to, construction of a pier, jetty, breakwater, boat ramp, or mining, drilling, or excavation. Projects that are exempted from the permit requirement include mosquito control activities authorized by the Department, construction of directional aids to navigation, duck blinds, foot bridges, boundary stakes, wildlife nesting structures, grazing or domestic animals, haying, hunting, fishing, and trapping.

The Department’s Wetlands and Subaqueous Lands Section issues permits. Applications for a permit are evaluated for environmental impact, aesthetic effect, the number and type of supporting facilities, including their environmental impact, and their effect on neighboring land uses. State, county and municipal comprehensive plans for the development and/or conservation of their areas of jurisdiction and economic effect also are considered. All applications are put on public-notice and any comments received are resolved prior to issuance of a permit.

Although not explicitly cited in the law or regulations, mitigation, in the form of creating compensatory wetlands, is required to offset the impacts of displacing wetlands for some public works projects, including those conducted by the state Department of Transportation.

The Wetlands Act has proven very effective in controlling destruction of tidal wetlands. During 1995 through 1996, less than one acre of tidal wetlands was permanently displaced under the permitting process.

Currently, the State of Delaware does not have a regulatory mechanism for protecting non-tidal wetlands. Nontidal wetlands comprise the vast majority of wetlands in the state, including the Chesapeake Basin. There are no efforts at this time to propose a non-tidal wetlands law.

2.6.9.5 The Subaqueous Lands Act

Rivers, streams, and other bodies of open water are protected under the state Subaqueous Lands Act (7 Del. Code, Chapter 72). The stated purpose of the Subaqueous Lands Act and the regulations written pursuant to the law is to protect subaqueous lands against uses or changes which may impair the public interest in the use of tidal or navigable waters. Subaqueous lands are defined as “submerged lands and tidelands.”

Subaqueous lands subject to jurisdiction under the law are shown on U.S. Geological Survey 7.5-Minute Series (Topographic) Quadrangle Charts for the State of Delaware. The law states that a permit is required for certain activities conducted in subaqueous lands. Activities include dredging, draining, or filling, and construction of any kind.

Permits are issued by the Wetlands and Subaqueous Lands Section. The Regulations Governing the Use of Subaqueous Lands stipulate that no activity may be undertaken which might contribute to the pollution of public waters, adversely impact or destroy aquatic habitats, or infringe upon the rights of public or private owners. The regulations specify the requirements for constructing boat docking facilities, shoreline erosion control measures, and activities involving dredging, filling, excavating, or extractive materials in public and privately owned subaqueous lands. Applications for permits are put on public notice to solicit public input. The application process is also coordinated with the Army Corps of Engineers.

To expedite the permitting process, a system of statewide activity approvals has been developed by the Wetlands and Subaqueous Lands Section. The statewide activity approvals provide an abbreviated review process and authorization for relatively small projects. Applicable projects range from
2.6.10 WETLAND FUNCTIONS AND VALUES

For many years, wetlands were viewed as disease ridden, worthless wastelands requiring filling, dredging, or channelization. This view has changed significantly in recent years, as the connection between wetlands wildlife, water quality, and other ecological and economic factors has been studied.

Research over the past couple of decades has found that wetlands provide many benefits to society. In fact, some of these values are vital to man’s existence. Wetlands intercept pollutants and nutrients from upland runoff and protect organisms dependent on clean water (humans included) from the poisonous effects of both nonpoint and point source pollution.

Ecological processes inherent in wetland ecosystems are usually described by functions. An example of a function would be wildlife habitat support. Further classification of a function, on the basis of its value, connotes usefulness to humans. The location of the wetland, human pressures on it, or the extent of the wetland may indicate the value of a functional ecologic process (Mitch and Gosselink, 1986). For example, clean water associated with wetlands provides drinking water to upland species, provides an uncontaminated environment necessary for many fish species, and ultimately, recreational value, in the form of hunting and fishing for humans.

It is important to keep in mind the differences between functions and values. Functions are things that a wetland does and are independent of our attempt to assign an arbitrary monetary value to them. In contrast, values are primarily human constructs, subject to whims of the marketplace. As a result, a wetland with a given function in one locality may be more highly valued than a wetland of similar function in another locality.

Because wetlands are diverse and occupy a variety of habitats, they do not all provide the same functions and values. Therefore, it is generally difficult to determine a wetland’s function without a specific site analysis. Variables to consider in assessing a wetlands function include wetland type, soils, hydrology, size, and adjacent land use.

Current development practices ignore the importance of preserving wetlands with specific functions crucial to maintaining the environmental integrity of a region or watershed. In other words, we have been allowing development in areas (i.e., wetlands) normally deemed unsuitable for conventionally designed septic disposal systems simply because recent technology has enabled us to site alternative septic disposal systems that overcome the limitations imposed by site hydrology. Such development has been carried out without any attempt to assign any ecological or monetary value to the lost wetland functions. Conversely, if we should eliminate alternative technologies, are we then “backdooring” a freshwater wetlands program through the septic site evaluation process?

According to Wohlgemuth (1991), wetlands offer three broad categories of values: fish and wildlife habitat values, environmental quality values, and socioeconomic values.

2.6.10.1 Fish and Wildlife Habitat

Wetlands provide food and habitat for a variety of fish, birds, mammals, amphibians, reptiles, and invertebrates. Some of these animals are either fully or partially dependent on wetlands to complete their respective life cycles. Most commercially important fish species, for example, are wholly dependent on wetlands for spawning and nursery areas. Wetlands also provide breeding ground and habitat for a variety of waterfowl species and fur-bearers. Some species of frogs, toads, and salamanders depend on wet habitat for their survival, and provide food for animals in higher trophic levels. Reptiles, such as turtles and snakes, use these areas for the same reasons as the above. Invertebrates, such as aquatic bugs or insects, are important in the maintenance of the food web.

Additional information on the interdependence of wetlands with fish and wildlife habitat can be found in the Living Resources section (2.7).

2.6.10.2 Environmental Quality Benefits

Wetlands are considered among the most productive ecosystems in the world. Wetland plants produce more plant material than most very productive cultivated farm fields. The major value of wetland plants occurs when the plants die and are broken down into detritus by bacteria and other microorganisms. Detritus forms the base of the food web that supports higher animals such as commercial fish species. Wetlands also help maintain and improve water quality.

The following are specific environmental quality benefits of wetlands:

- Pollutant removal (heavy metals, pathogens)
- Sediment trapping
- Nutrient uptake and recycling
- Oxygen production
- Wastewater treatment
- Storm-water treatment
2.6.10.3 Socioeconomic Values

Some of the benefits that wetlands provide are benefits of more tangible economic value, such as protection from flood and storm damage. Because these benefits provide dollar savings, they tend to be more appreciated.

The following are some socioeconomic wetland values:

- Flood and storm-water damage protection
- Erosion control
- Water supply and ground-water recharge
- Natural products supply (e.g., timber, fish, wildlife, firewood, etc.)
- Recreation (e.g., waterfowl, fishing, boating, nature study, etc.)

2.6.11 DATA GAPS AND RECOMMENDATIONS

1. Need to develop baseline wetland losses in Chesapeake Basin and identify areas that are losing wetlands due to urbanization and/or agriculture.
2. Recommend that the Department develop BMPs for pond maintenance and remediation.
3. Promote the acquisition and protection of wetlands and natural heritage sites.
4. Adopt department-wide comprehensive wetland plan.
5. Examine current pond management approaches and develop a more effective, broad-based management approach. Educate pond managers and concerned public to the problems confronting the eutrophication problem in ponds.
6. Establish a methodology for discouraging development in Sensitive Areas.
7. Adopt statewide wetland mitigation policy. Include the concept of “Land Banking.”
8. The Statewide Wetland Mapping Project data should be compared with the Natural Heritage Inventory to identify areas where additional research and/or protection are needed.
9. Develop Best Management Practices and an accompanying manual that promotes riparian buffers to help trap nutrients and improve water quality in both channelized and natural streams.
10. Promote the establishment of forested wetlands and upland forest to supplement and/or restore natural riparian buffers.
11. Implement the channelization BMP manual that promotes riparian buffers to help trap nutrients and excessive overland runoff. Alternative maintenance techniques should be considered, including saving trees, mowing along one side of ditch, use of herbicides for those landowners who refuse to establish woody vegetation, or not mowing at all.
12. Educate the agricultural community and other people affected by ditching that drainage and wetlands habitat can coexist if managed properly.
13. Require the use of existing and new BMPs for channel construction activities.

2.6.12 REFERENCES


2.7 LIVING RESOURCES

2.7.1 INTRODUCTION

By the beginning of the 16th century, the land that would become the political entity known as the State of Delaware encompassed a region of outstanding natural diversity. Clear freshwater rivulets tumbled down rocky streams and rivers from the hills of the Appalachian Piedmont Plateau into the drowned Susquehanna and Delaware River valleys. These river valleys broadened into two magnificent bays, the centers of two vast estuaries, bordered with productive coastal marshes, abundant with shellfish and waterfowl that isolated the intervening coastal plain lands into an elongated peninsula. The larger of the two estuaries, Chesapeake Bay, formed the western boundary of the Delmarva Peninsula. The headwaters of many rivers and streams that enter Chesapeake Bay originate in what is now Delaware.

Today, following nearly 400 years of natural resource consumption and the conversion of habitats by an ever-increasing number of immigrants for agricultural, residential, and industrial purposes, Delaware’s remnant natural areas (woodlands, rivers, swamps, and marshes) still provide a biological history of Delaware. Yet, these natural remnants are under continual, increasing, and unprecedented new pressures from humans. This portion of the document will assess the current status of these living resources, measure their spatial change and trends, outline protection and restoration efforts, and suggest possible solutions to retaining a dynamic natural resource base for Delaware’s future.

2.7.2 CHARACTERIZATION

In many ways, our living resources reveal more about the state of our environment than any other factor. Our native species are generally the first indicators of change or disruption. They experience first-hand the direct impact of habitat loss, degraded air and water quality, and competition from exotic species. In particular, studies of rare and declining species can play special roles as environmental indicators. These are often the species most sensitive to environmental change and habitat degradation, and hence can bring the first hints of environmental impact. The trick is in knowing how to observe and understand nature’s messages.

For instance, a stream’s invertebrate fauna tells volumes about the water quality in a tributary. Although not usually included as a standard water quality indicator, the diversity of freshwater mussels is an excellent tool for understanding the health of a waterway. Mussels are filter feeders and hence are especially sensitive to the effects of sedimentation and pollutants. Furthermore, many mussel species require the presence of particular fish species onto which their larvae must attach to complete their life cycle. When native fish species decline because of loss of habitat, damming of streams, or introduction of non-native fish, mussels are often the first to feel the impact.

Changes in an area’s avifauna can also illustrate the accumulated environmental changes that often proceed unnoticed. Steep declines in insectivorous forest birds may
indicate the loss or fragmentation of mature forests in our area. Increased numbers of American robins are in some ways comforting after the scare of Silent Spring in the early 1960s, but are also, unfortunately, reminders that fields, pastures, roads, and mowed lawns have replaced most of what used to be forest. Similarly, the presence of increasing numbers of non-migratory Canada geese is largely a result of human changes to the landscape, and the intentional introduction of goslings, which had no motive or inclination to migrate. Ironically, these large numbers of “transplanted” geese can lull the uninformed into complacency about their environment when, in fact, migratory Canada geese are experiencing region-wide declines.

There have been a number of studies, both ongoing and short-term, of the Chesapeake Basin’s flora and fauna. Fish and waterfowl are probably the two best-studied groups of species. Annual waterfowl counts date back to 1955, with more than twenty years of species-specific counts (Whittendale, 1996). Fish species were inventoried for all of Delaware’s major streams in 1988, and summarized in two reports funded by the Federal Aid in Fisheries Restoration Act (Shirey, 1988; 1991).

The Delaware Division of Fish and Wildlife’s Nongame and Endangered Species Program has conducted ongoing studies of some of the Basin’s rare and declining species. The federally endangered Delmarva Fox Squirrel, once found in the forests of Delaware, was extirpated from the entire state. Reintroductions have been moderately successful in eastern Sussex County, but have not been attempted in the Chesapeake Basin, in part because of a federal moratorium on new releases.

The Delaware Natural Heritage Program (DNHP), part of the Division of Fish and Wildlife, conducts on-going inventories of natural communities as well as rare and declining species, (e.g., state and globally rare plants, birds, insects, mussels, reptiles, and amphibians). It maintains a database, both electronic and manual, of its findings throughout the state. The DNHP has never conducted a comprehensive review of the status of biodiversity in the Chesapeake or any of Delaware’s basins. But from data that have been collected, it is commonly accepted that an alarming number of species which were once common are now found at only one or two locations, or are extirpated entirely. Of the 50 states, Delaware has been estimated to have lost the highest proportion of its native flora (Kutner and Morse, 1996).

2.7.2.1 Emergence of Delmarva Habitats

The modern habitats of the Chesapeake Basin have their origins in the relatively recent past. Delaware’s Coastal Plain Province is young by comparison to the Piedmont’s 500-million to billion-year-old rocks. Built by depositions of ancient sediments over the last 150 to 200 million of years, the coastal plain has been repeatedly inundated and exposed by rising and dropping sea levels. These sediments were eroded from Piedmont and Appalachian highlands and deposited along the margin of the continent by the Delaware and Susquehanna rivers when the ocean covered the peninsula. The last time this happened was during the Sangamon interglacial event when the ocean was 30 feet higher than today. Since the Sangamon ended, approximately 80,000 years ago, the peninsula has remained above sea level. In fact, when the Wisconsin Glacier advanced southward around the globe from the Arctic 25,000 years ago, it trapped so much of the world’s water that the ocean dropped 300 feet below modern levels, perhaps doubling the modern dimensions of the peninsula. This sheet of ice approached as far south as mid-New Jersey and greatly influenced the types of plants and animals that inhabited Delaware’s coastal plain (Scott, 1991).

The cold air mass associated with the huge ice sheet covering the globe produced very cold, cloudy, wet weather over the peninsula. This pattern persisted until about 12,000 years ago when a dramatic warming trend and a melting ice sheet increased the levels of precipitation and caused a rise in the ocean level that continues today. During this period, a shift in the peninsula’s vegetation occurred. Tundra-like grassland with scattered boreal species such as spruce had occupied the peninsula during the height of the glacial period. As the weather warmed, northern boreal forest with intermittent remnant grass openings covered the landscape. About 10,000 years ago, pine replaced spruce as the dominant species in this coniferous forest. Over the next 2,000 years, hemlock became a major component on the peninsula, while oaks first began to appear in these moist, mesic (well-drained) forests. During this period, the extinction of the mammoth, mastodon, giant beaver, and other megafauna left a largely modern group of animals on the peninsula. The warm moist weather pattern continued for over 5,000 years until the peninsula supported dense mesic forest, with numerous areas of swamps.

A drying trend began around 5,000 years ago in the Mid-Atlantic, and peaked from 4,700 to 2,200 years ago (Custer, 1984). This xerothermic period had dramatic effects on the flora of the peninsula, bringing about an increase in drought tolerant oak-hickory forest, an eastward extension of prairie grasslands, and a reduction or loss of many mesic species, including hemlock. Also about this time, sea-level rise slowed enough to allow the formation of the estuarine marshes in Chesapeake and Delaware bays (Kraft, 1977). Once the dry trend was replaced by moister and cooler weather, a landscape that approximates modern Delaware emerged.

The Chesapeake Basin’s modern flora and fauna associations have existed in similar form on the peninsula for the last 2,000 years. The ocean is still rising, slowly shrink-
ing the size of the peninsula, and demonstrating that weather patterns are constantly and inextricably linked to the future of the Delmarva Peninsula. But perhaps the quickest changes to the living resources in the Chesapeake Basin, and to the entire peninsula, have occurred over the last four centuries since the period of European contact with Native Americans.

2.7.2.2 Prehistoric Human Impacts

It was during the post-glacial period, possibly as far back as 15,000 years ago, when man first ventured onto the peninsula. These were a stone-age people that criss-crossed the landscape in search of food. All they left behind was their stone tools, although some attribute the extinction of the megafauna to these skilled hunters (Martin, 1984). But these people brought another tool with them, fire, which they frequently applied to the landscape to drive game, maintain wildlife pastures, and for other uses (Pyne, 1982). The introduction of anthropogenic fire, added to the much more infrequent natural fire regime, was a major factor in shaping the modern Chesapeake Basin ecosystem. The introduction of fire favored fire-resistant species, such as oak and pine, over hemlock and other fire-vulnerable species.

The descendants of these Native Americans followed similar lifestyle patterns until approximately 1,000 years ago, when they developed a more sedentary life-style based, in part, upon domesticated plants. Growing of plants such as corn, beans, squash, and melons began to supplement the hunting and wild food gathering traditions. However, seasonal burning of the landscape continued until the first Europeans landed in Delaware.

2.7.2.3 Historic Human Impacts

By the 17th century, initial European settlement of the Chesapeake Basin had begun, not by the Dutch or Swedes, but by the English. Lord Baltimore believed that the Eastern Shore was part of his proprietorship, so he granted warrants for land along both the Nanticoke River and Marshyhope Creek that included parts of modern Delaware. These early settlers were subsistence farmers at first, growing rye, barley, tobacco, and sugar cane, and planting apple and peach orchards. Later in the century, they abandoned tobacco and sugar cane and began to grow wheat and corn as cash crops. They introduced hogs, horses, sheep, and cattle to the peninsula and released them into the woods. They adopted the Native American method of burning the landscape, partially out of defense, but also to clear the forest. They girdled the larger trees and planted under them, cutting the smaller trees and shrubs. Their homesteads were usually located within 300 feet of the stream on which they fronted. Transportation was by water, but sedimentation, dead logs, and ship ballast blocked many previously navigable waterways. By the beginning of the 18th century, most of the remaining Native Americans, that had not been ravaged by disease, had left the peninsula or had adapted to the predominant Euro-American society.

During the 18th century, the colonial settlement pattern began to extend away from stream banks into remote upland sites within a half-day of travel (maximum eight miles) from the local grist and sawmills. Beginning in the 1760s, several iron furnaces were established along the Nanticoke, Gravelly Branch, Deep Branch, and other locations in the Chesapeake Basin. These furnaces processed bog iron deposits dug from the surrounding wetlands (Heite, 1974). The forges required prodigious amounts of charcoal and wood to operate, and these were acquired from the surrounding forests. Most of these furnaces were out of production by the American Revolution. By 1770, the boundary dispute between Maryland and Pennsylvania was settled, and the Chesapeake Basin became part of the Lower Three Counties of Pennsylvania. The rapid growth of Delaware’s population during this period, especially in “New Sussex,” as the previously disputed territory was called, forced many new farmers to clear and farm land of poor quality. Streams and creeks were dammed to provide power for saw and gristmills. The milldams became focal points as well as crossing points for the surrounding population, with taverns, shops, stores, and cart paths developed near these dams. The lumbering of the peninsula increased rapidly and continued unabated. Not only were the forests an impediment to agriculture, but wood was needed for many purposes, including new construction, energy, furniture, shipbuilding, bridges, and charcoal. Even the ancient submerged giant cypress logs that had fallen into the swamp long before the colonies existed were pulled from the Great Cypress Swamp and made into shingles (Scharf, 1888).

In the early 19th century, agricultural production had fallen. Many farms were abandoned in the 1820s and ’30s when farmers left for better lands to the west of the mountains (De Cunzo and Catts, 1990). Although these abandoned, played-out farms could no longer support 19th-century farming practices, they quickly developed young healthy secondary forests of loblolly pine. Still, by 1880, between 75 and 90 percent of each county was farmland. Virtually every upland habitat had been cleared. This practice had been driven in part by the arrival of the railroad, which, after reaching Seaford in 1858, provided a fast route to market for farmers in the western part of Delaware. By 1890, Sussex County produced peaches, corn, and enormous amounts of strawberries (by 1900, Sussex County led the nation in strawberry production).

The successful introduction of European agricultural practices meant not only a conversion of a significant per-
per centage of forest to agriculture and pasture, but the exter-
mination of predators, and the over-harvesting of game
and furbearing animals. Beaver had been trapped out with
the first fur traders in the 17th century. Great flocks of
passenger pigeons had once returned annually to a
“pigeon-roost,” or breeding place, in the great oak groves of
the Moysemsing, the Native American descriptive
word for an unclean place or dung-heap (Scharf, 1888).
The huge flocks of pigeons quickly disappeared from
Delaware with the cutting of the trees, long before the
species became extinct in 1914. Numerous species were
exterminated from Delaware near the end of the 19th cen-
tury, including eastern gray wolves, eastern cougar, and
black bear. Wild turkey fell to logging practices and mar-
ket hunting by 1880, but were later reestablished. White-
tailed deer were essentially gone from Delaware by 1900.
In fact, deer hunting was illegal in Delaware for over 150
years, until the 1950s.

The holly wreath industry flourished from the 1880s
through 1960s in Sussex County. Most of the large mar-
ketable holly was cut for wood products, while smaller
boughs went into making large quantities of holly wreaths.
Although largely centered in eastern Sussex, Bridgeville
was the major shipping point for holly wreaths collected in
the Chesapeake Basin during November and December of
each year. Collecting wreaths supplemented farm incomes
during this time of year, especially during the Depression
(Hancock, 1976).

Despite the almost constant lumbering of Delaware’s
forests beginning with the earliest settlements in the 17th
century, a record amount of timber was harvested in 1909
(records were not kept prior to the Civil War). Fifty-five
million board feet of lumber was shipped from Sussex
County, mostly secondary growth loblolly pine that had
naturally reestablished on abandoned farms and other
clearings 100 years previous. Charcoal production was
also an important industry and still persisted in the
Redden area as late as the 1950s (Passmore, 1978).

2.7.2.4 Biotic Communities

The following DNHP descriptions summarize the natural
communities found within Delaware’s Chesapeake Basin.
Because the Basin ranges over 81 miles from north to
south, it includes a significant transition zone where a num-
er of northern plant species reach their southern limits of
natural distribution, while an even greater number of south-
ern species reach their northern distribution limit. Despite
the low elevations and generally simple topography
throughout the Basin, a wide assortment of habitat types
harbor a diverse flora and fauna.

Forest Communities

The Chesapeake Basin is home to a variety of impor-
tant forest communities that are found as repeating units
on the landscape. These forests would fall within the
broadly classified Mixed Mesophytic Forest Region in the
northern portion of the Basin and gradually transitioning
in the south to the Oak-Pine Forest Region (Braun, 1950),
or the Oak-Pine-Hickory Forest Sub-Region, according to
Greller (1988). In general, the northernmost forests in the
Chesapeake Basin are comprised of a mixture of hard-
woods, dominated primarily by oaks, beech, tulip poplar,
and hickories on the drier sites. The predominate tree
species in a wide variety of wetland habitats include box
elder, sycamore, sweet gum, slippery elm, red maple, tulip
poplar, ash, pin oak, and sometimes river birch and black
willow. The farther south one travels in the Basin, a tran-
sition in forest species begins, but nowhere is this more
dramatic than as one enters Sussex County. Here, the
deciduous hardwood-dominated forest gives way to an
evergreen forest with a distinctive southern feel. This is
the Oak-Pine Forest Region.

Two major components have been virtually eliminated
from both of these forest types. American chestnut
(Castanea dentata) and, to a lesser degree, American elm
(Ulmus americana) were formerly important components of
both of these forest regions, but have been virtually elimi-
nated by the introduction of chestnut blight and “Dutch”
elm disease. A new threat, anthracnose fungus (Discula
destructiva), which attacks flowering dogwood (Cornus
floridana), is predicted by some to wipe out this significant
understory tree from Delaware forests in the near future.

At one time, the Chesapeake Basin was virtually entirely
forested. Native American fire practices opened park-like
gaps within the forest and altered the upland composition
of the forest. Consequently, over the thousands of years of
use, burning favored fire-tolerant species such as oak and
pine over maple, beech, and hemlock. When European
colonists arrived, they cleared the land with incredible
speed relative to their numbers. They permanently frag-
mented and isolated the forest into small, scattered wood-
lots. The first areas to be cleared were upland forest
habitats. These areas provided the best-drained farmland
and easy accessibility. As a result, intact, old growth,
upland coastal plain forest probably no longer exists in
Delaware. At first, the colonists avoided swamps and other
wet forestlands. These forests were protected by their
waters, which had also generally insulated them from
Native American fires for millennia. But even these forests
could not avoid the ax. In a trend that continues today,
forests too wet to farm are regularly used for wood supply,
livestock, hunting, and timber products. Many have had
their hydrology altered by successful (and even unsuccess-
ful) attempts at drainage. All of the forested stream corri-
dors in the Chesapeake Basin have been dammed,
dredged, or have been used for irrigation. Still, somewhat
amazingly, after the consistent and resourceful efforts to uti-
lize these forests, a variety of wetland forest types remain.
However, because of their heavy utilization for over 200 years, there is tremendous variability in the quality of these forests. In all probability, the woodlands throughout the Chesapeake Basin are second-, third-, or even fourth-growth forest, most with trees less than 50 to 100 years old. Because of these repeated disturbances, many forest-dependent plant and animal species in Delaware are threatened with extirpation. The greatest loss of species throughout the state has occurred in forested habitats. Yet, the oldest trees in the state are to be found in this Basin, where one forested wetland contains specimens estimated at 500 years of age. Although the age of these magnificent trees is unusual in Delaware, and indeed in the entire Chesapeake watershed, many of these huge plants are just reaching middle age. Although the term “old growth” is frequently used to describe patches of forest containing these large specimens, a true, virgin, old-growth forest is not likely to remain in the Chesapeake Basin. However, some of these mature forest patches are developing some of the typical characteristics of an old growth forest.

Nearly 75 percent of the Chesapeake Basin’s terrestrial forests are no longer extant, having been cleared long ago for farmland and early settlements, or more recently for urban sprawl. Most of the remaining forests throughout the Basin are young successional woods or maturing forests that are comprised of a high proportion of pioneer tree species that quickly reforest abandoned farmland or timber clear-cuts. A significant transition from loblolly pine forest to red maple and sweet-gum forests occurred during the 1960s and ’70s as a result of clear-cutting second- and third-growth loblolly pine forest (Ferguson and Mayer, 1974). Twentieth-century forest practices that encouraged planting loblolly pine seedlings and suppressing hardwood competition with herbicide and mechanical means has lead to an increase in timber plantations and a further reduction in structural and functional forest diversity.

The following are brief descriptions of the forest types that one is likely to encounter in the Chesapeake Basin along its entire length in Delaware:

**Quercus spp.-Liriodendron tulipifera-Fagus grandifolia Forest Community (oak–tulip poplar–beech forest)**

This community is usually found in scattered small stands or “rich woods” in the coastal plain. The oak–tulip poplar–beech forest may be extremely diverse and of good to excellent quality. Oaks usually present include red oak (*Q. rubra*), southern red oak (*Q. falcata*), scarlet oak (*Q. coccinea*), and white oak (*Q. alba*). Common associates include Fraxinus americana, Carya ovata, C. glabra, C. tomentosa, Lindera benzoin, Kalmia latifolia, Hamamelis virginiana, Carpinus caroliniana, Rhododendron periclymenoides, Viburnum prunifolium, and Cornus florida, among other woody taxa. Herbs are typified by such species as Arisaema triphyllum, Podophyllum peltatum, Asarum canadense, Claytonia virginica, and Aralia nudicaulis, among a host of other species.

**Liriodendron tulipifera Forest Community (tulip poplar forest)**

This is a forest community where the majority of the canopy is comprised of tulip poplar. This is similar to the preceding community but without the oaks and beech (though certainly these may be present but in low numbers). The understory may be comprised of many of the same species as in the previous community.

**Acer rubrum Wetland Forest (red maple wetland forest)**

This forest can be found on narrow or broad floodplains. While red maple (*Acer rubrum*) may be the dominant canopy tree, several additional canopy associates may include sweet gum (*Liquidambar styraciflua*), black gum (*Nyssa sylvatica*), green ash (*Fraxinus pennsylvanica*), pin oak (*Quercus palustris*), and sycamore (*Platanus occidentalis*). The subcanopy woody layer is comprised of Cornus amomum, Clethra alnifolia, Itea virginica, Lindera benzoin, Vaccinium corybosum, Leucothoe racemosa, Viburnum nudum, and *V. dentatum*, among others. Herbs may include various sedges (*Carex* spp.), Symplocarpus foetidus, Juncus effusus, Impatiens capensis, Scirpus cyperinus, Phalaris arundinacea, Solidago rugosa, Aster subsp., Arisaema triphyllum, Onoclea sensibilis, Acorus calamus, Chelone glabra, Thelypteris palustris, Woodwardia areolata, and Boemeria cylindrical.

**Acer rubrum-Liquidambar styraciflua Forest Community (red maple-sweet gum forest)**

Q. marilandica, Vaccinium stamineum, Gaylussacia baccata, G. frondosa, Magnolia virginiana, Cornus florida, and Myrica pensylvanica. Herbs are sparse with Panicum spp., Carex spp., Chimaphila maculata, Cypripedium acaule, and Melampyrum lineare, typical. Vines include Smilax rotundifolia, S. glabra, Partbenocissus quinquefolia, Toxicodendron radicans, Vitis aestivalis, V. rotundifolia, and Ipomea pandurata. Lichens and mosses may or may not be prevalent. This community type occurs in sandy, well-drained substrate.

Quercus spp.-Carya spp. Forest Community (oak-hickory forest)

This community can be found in drier habitats where there has been little disturbance, usually at the highest elevations on the more level uplands. It is characterized by an abundance of oaks (Q. alba, Q. rubra, Q. coccinea, Q. falcata) and hickories (C. cordiformis, C. ovata, C. glabra, C. tomentosa). Associates include Liriodendron tulipifera, Acer rubrum, Betula lenta, Fraxinus americana, Hamamelis virginiana, Kalmia latifolia, V. dentatum, Cornus florida, Lindera benzoin, Euonymus americanus, Lonicera japonica, Prunus serotina, Ariseama triphyllum, Aralia nudicaulis, Chimaphila maculata, Galium spp., Circaea lutetiana, Sanguinaria canadensis, Epipogus grandifolia, Podophyllum peltatum, Smilacina racemosa, and Thelypters noveboracensis (Clancy, pers. comm.).

Scrub-Shrub Communities

Scrub-shrub communities can be quite variable, are generally small, and may represent an early seral stage of a forested community. Many of the scrub-shrub communities are more accurately described as impenetrable thickets, with a dense understory of brambles and greenbrier. The more persistent scrub-shrub communities are usually found along stream sides and seepage wetlands, and are often situated between marsh and forest habitats. Shrubs communities recur within the Nanticoke watershed. Examples include (1) Alder Shrub Community dominated by Alnus serrulata and A. maritima; (2) Red Maple-Green Ash Swamp Rose Shrub Community, a low statured and stunted shrub assemblage due to flooding; and (3) Mixed Shrub-Mixed Herb Community representing a diverse assemblage of shrubs, herbs, and stunted trees (Clancy, pers. comm.).

Herbaceous Communities

Examples of the herbaceous communities within the Chesapeake Basin include the following: Tussock Sedge Herb Community (Carex stricta); Reed Canary Grass Herb Community (Phalaris arundinacea); Cat-tail Herb Community (Typha latifolia, T. angustfolia); Indian Rice Herb Community (Zizania aquatica); Pickerel-Weed - Arrow Arum Herb Community (Pontederia cordata, Peltandra virginica) abundant on the Nanticoke River; Mixed Forbs Tidal Herb Community; Spatterdock Herb Community (Nuphar lutea); Water Lily Herb Community (Nymphaea odorata); Quillwort Herb Community (Isoetes riparia); Tape Grass Submerged Herb Community (Vallisneria americana, Potamogeton spp.) (Clancy, pers. comm.).

Rare Community Types

The DNHP, in an ongoing process of describing and classifying natural communities within Delaware, located and mapped several unique and significant community types in the Chesapeake Basin (McAvoy and Clancy, 1993). Map 2.7-1 Living Resources shows these locations along with other natural areas.

Bald Cypress Communities

The DNHP considers naturally occurring bald cypress (Taxodium distichum) to be a rare species in the State of Delaware, including the Chesapeake Basin. This tree species has a relatively limited distribution and is found in only four watersheds in the state, two of which are in the Chesapeake Basin (e.g., Nanticoke and Pocomoke). The tree has a low number of natural occurrences within Delaware, where it reaches the northernmost limit of its North American range.

Bald cypress wetland communities are principally found on the forested floodplains of rivers and creeks that are temporarily and seasonally flooded. These wetland communities are considered to be climax communities in Delaware because of their extensive canopy coverage, large size, and potential life span. On floodplains, bald cypress is rarely found growing in pure, mono-specific stands. It is typically associated with a mix of hardwood species, such as red maple (Acer rubrum), black gum (Nyssa sylvatica), sweet gum (Liquidambar styacifa), and green ash (Fraxinus pennsylvanica). The James Branch and its tributaries contain the most extensive and finest examples of bald cypress wetlands in the state (McAvoy and Clancy, 1993). The cypress-hardwood association may be indicative of a short hydroperiod because most other tree species can not have their roots submerged for extended periods of time. This is clearly demonstrated where floodplains have been dammed, creating ponds. The only trees still surviving in these ponds are bald cypress. Bald cypress trees are adapted to prolonged flooding that would exclude other tree species. Some conifers such as Atlantic white cedar (Chamaecyparis thyoides) and lobolly pine (Pinus taeda) may also be associated with bald cypress wetlands.

The shrub and herbaceous layers of these floodplain wetlands are very diverse. However, the species found in these wetlands are often also common to hardwood floodplain wetlands as well. According to McAvoy and Clancy (1993), the bald cypress floodplains were not found to contain rare species outside of the bald cypress itself.

The headwaters and tributaries of the Pocomoke River encompass a portion of the area known as the Great Cypress Swamp. Much of the Pocomoke River and its tributaries have
been greatly altered by wide and deeply cut dredge channels. As a result, the riparian floodplain community has been severely affected, with the wetland herbaceous habitat of the floodplain swamp forests reduced to a remnant of its former self. Weedy species such as Japanese honeysuckle (*Lonicera japonica*), poison ivy (*Toxicodendron radicans*), pokeweed (*Phytolaca americana*), multiflora rose (*Rosa multiflora*), hercules club (*Aralia spinosa*), wild grape (*Vitis* sp.), greenbrier (*Smilax rotundifolia*), and paw paw (*Asimina triloba*) have invaded the altered habitat and are now well established and abundant. Red maple, sweet gum, and black gum have replaced the formerly dominant bald cypress tree canopy. Sweetleaf is abundant throughout the Pocomoke River watershed. However, bald cypress remains only in sporadic stands in this watershed following the extensive 18th- and 19th-century logging, drainage, and subsequent wildfires that have greatly altered the hydrology and, consequently, available habitat.

**Atlantic White Cedar Communities**

Atlantic white cedar (*Chamaecyparis thyoides*) is a wide ranging, but uncommon tree species found in a narrow, interrupted belt scattered along the Atlantic coast from Maine to Florida, then west along the Gulf coast to Mississippi. The historical distribution of Atlantic white cedar on the Delmarva Peninsula is reported to be either very sketchy or limited. According to Dill and others (1987), Atlantic white cedar exists today on the Delmarva Peninsula in remnant stands that represent only a fraction of the species’ former geographic and ecologic importance.

The many uses of Atlantic white cedar and its commercial exploitation are well documented in the literature (e.g., Little, 1950; Frost, 1987; Zampella, 1987; Laderman, 1987). Since colonial times, this tree has been logged repeatedly. Because the wood was lightweight, easily worked, and resistant to decay, it had many uses during the colonial period. Many Atlantic white cedar stands have been logged two, three, or more times in the past, not surprisingly making the tree a minor element in the landscape today.

Significant remaining populations of Atlantic white cedar are in Delaware’s portion of the Chesapeake Basin, in the Nanticoke River watershed and its associated tributaries. Several small remnant populations exist in the Great Cypress Swamp in the Pocomoke drainage. A past estimate (Anonymous, 1797) claimed that one-fifteenth of the 50,000-acre Great Cypress tract contained green “cypress” (Atlantic white cedar). This anonymous author further states, “Beautiful green cypress, or rather cedar, whose regular and majestic height cast such a venerable shade that it kept every other tree of the forest at an awful distance and impressed the beholder with a religious solemnity.” If this estimate is true, approximately 3,333 acres of the Great Cypress Swamp consisted of this tree species. Today, only 10,000 acres of the great swamp remain, and virtually none of these acres is hydrologically intact or vegetated with bald cypress or Atlantic white cedar.

In its natural range, Atlantic white cedar is typically found along creeks and rivers (Laderman, 1987). In Delaware, it formed dense stands at the headwaters of colonial period millponds in portions of Kent and Sussex counties. Atlantic white cedar wetlands occur on very poorly drained, highly organic acid soils. These soils are described as muck-peat and range in thickness from a few inches to many feet. The cedars occur on hummocks of organic matter, leaf litter, and developing soils, surrounded by hollows that are flooded for lengthy periods of time (McAvoy and Clancy, 1993).

Where Atlantic white cedar forms pure stands, typical associated understory species include Collin’s sedge (*Carex collinsii*), sweet pepperbush (*Clethra alnifolia*), inkberry (*Ilex glabra*), Virginia willow (*Itea virginica*), spicebush (*Lindera benzoin*), sweet bay (*Magnolia virginiana*), partridge berry (*Mitchella repens*), golden club (*Orontium aquaticum*), swamp azalea (*Rhododendron viscosum*), greenbriers (*Smilax laurifolia* and *S. wallert*), sphagnum moss (*Sphagnum spp.*), highbush blueberry (*Vaccinium corybosum*), arrowwood (*Viburnum dentatum var. lucida*), and possumhaw (*V. nudum*). Generally, except where openings occur in the cedar canopy, the overall floral diversity is lower in these swamps than in mixed white cedar/hardwood swamps. However, these openings often harbor a plethora of rare species (McAvoy and Clancy, 1993).

Where Atlantic white cedar is not the dominant canopy species and co-occurs with other tree species (most notably, red maple, green ash, and black gum), there tends to be greater diversity of shrubs and herbs in the understory. In addition to the species mentioned above that are found in a pure Atlantic white cedar community, these woody species are commonly found in a mixed cedar-hardwood swamp: seaside alder (*Alnus maritima*), red chokeberry (*Aronia arbutifolia*), persimmon (*Diospyros virginiana*), strawberry bush (*Euonymus americanus*), American holly (*Ilex opaca*), winterberry (*Ilex verticillata*), fetterbush (*Lewtcothoe reae- moso*), sweet gum, tulip poplar, wax myrtle (*Myrica cerifera*), mistletoe (*Phoradendron flavescens*), loblolly pine, Virginia pine (*Pinus virginiana*), and greenbrier (*Smilax rotundifolia*) (McAvoy and Clancy, 1993).

Atlantic white cedar wetlands in Delaware and throughout their range are considered refugia for both state and globally rare species.

**Coastal Plain Pond Communities**

Coastal plain ponds (also known as Carolina or Delmarva bays, whale wallows, etc.) are characterized as shallow elliptical or ovate variable-sized depressions oriented in a southeast-northwest direction. However, in Delaware, coastal plain ponds are usually less than an acre in size, and may or
may not have the southeast-northwest orientation. Frequently, a pronounced sand ridge may be on the southeast side of the pond. A prominent rim circumscribing the pond is also a common characteristic, although not always present. Most of the ponds are located in Delaware’s portion of the Chesapeake Basin, and are primarily in northwest Kent and southwest New Castle counties.

The origin of coastal plain ponds is a mystery. The ponds occur in the sandy soils of the Atlantic Coastal Plain, from New Jersey to Florida, and are positioned on several different geologic formations (Prouty, 1952; Gamble et al., 1977). On the Delmarva Peninsula, the coastal plain ponds occur on the Wicomico, Talbot, and Pamlico terraces, between sea-level and 90-feet elevations, in the Pennsauken and Calvert formations (Rasmussen, 1958; Pickett and Spoljaric, 1971; Benson and Pickett 1986; Stolt 1986; and Stolt and Rabenshors, 1987). At the present time, there is no accepted explanation of coastal plain pond formation.

Soil studies of coastal plain ponds in Maryland indicate the soils have low pH values (from 3.6 to 4.6); are poor to very poorly drained; and range from silt loam to silty clay loam at one extreme, to loamy sand at the other (Stolt and Rabenshors, 1987). Coastal plain ponds in Delaware have similar textural characteristics as the Maryland coastal plain ponds. Most coastal plain ponds in Delaware are characterized by fluctuating water tables and are mainly derived from groundwater recharge in the winter. As a result of ongoing biological surveys by DNHP staff, it is surmised that these fluctuating water tables contribute to the establishment of much of the unique herbaceous flora, while often precluding establishment of most woody species, such as shrubs and trees. Moreover, DNHP estimates that as a result of anthropogenic activities (subdivisions, channelization, etc.), more than half of the known coastal plain ponds have been destroyed or have severely disrupted hydrology.

According to a 1993 DNHP survey, the majority of the coastal plain ponds (which occur in the west-central portion of the state within the Chesapeake Basin) are degraded. Impacts to the ponds resulted from perturbations of the local ground-water supply due to clear-cutting of adjacent forest habitat, channelization of natural streams, and ditching to drain nearby agricultural lands. These activities are thought to have altered the environmental character of these systems by disrupting the surficial and subterranean water supply and affecting water quality of the ponds.

Coastal plain ponds are important to preserve and protect. They are critical refugia for a variety of endangered species of animals and plants and are geologically unique entities with no definitive origin. They provide a unique and local habitat for the Delmarva Peninsula complex of flora and fauna. They are important for local ground-water recharge to maintain adequate drinking water and baseflow for streams. Efforts to protect these wetlands via acquisition, public outreach programs, or regulatory protection will be necessary if we are to preserve this unique resource.

Xeric Sand Dune Ridges

These dry sand dune ridges are a unique natural community type to Delaware and the Delmarva Peninsula. They are most prominent within the Nanticoke River Watershed, where the best development of xeric sand-ridges is found along the east side of the river. Thought to have originated from Parsonburg Sand deposited between 13,000 and 30,000 years ago (Denny and Owens, 1979), the distribution of this community is irregular. Some are found in groups, while others are isolated. Forested with a mix of oak and pine, the ridges are long, narrow, and irregular in shape, and of low relief with gentle sloping sides. Dominated by Virginia pine (Pinus virginiana) with a variety of oaks, this “barren” type of community, with its low canopy (6 to 40 feet), supports an understory of low heaths, and a sparse herbaceous layer characterized by sedges, grasses, lichens, and mosses (Clancy, pers. comm.). This community appears to be fire-dependent and has been somewhat altered by modern fire suppression.

2.7.2.5 Wildlife

Game Populations

There are 58 species currently classified as “Delaware game animals” and managed by the Division of Fish and Wildlife (F&W). Among these species are 44 birds, 11 mammals, 2 reptiles, and 1 amphibian. All of the mammals, reptiles, and amphibians, as well as 6 bird species, are year-round residents. The remaining 38 bird species are classified exclusively as migratory and fall under the jurisdiction of the U.S. Department of the Interior.

The white-tailed deer (Odocoileus virginianus) is native to the Chesapeake Basin and has adapted and thrived in the human-altered habitat. Deer damage to agricultural crops has become a serious concern within Delaware. The Basin includes most of the top deer management zones in terms of the number of crop damage complaints and severity of damage. Since 1992, the deer harvest within the Basin has increased approximately 53 percent, far exceeding the overall statewide increase of 36 percent. Crop damage complaints and deer harvest levels indicate that the white-tailed deer population is at high levels within the Chesapeake Basin.

Beaver (Castor canadensis) was apparently extirpated from Delaware by the mid-1800s. They were reintroduced to the state in 1935 with the release of one pair in each county. Since then, additional animals have moved in from Maryland. In 1943, the population was estimated at 24 animals. By the mid-1980s, the beaver was beginning
to come into conflict with humans, primarily because of road and field flooding and destruction of trees. In 1990, Fish & Wildlife captured and relocated 28 problem animals in Sussex and southern Kent counties. A 1991 survey of beaver colonies found 126 statewide, with approximately 90 of those in the Chesapeake Basin. In 1997, there were an estimated 300 colonies within the Delaware portion of the Basin, with a population in excess of 1,500 animals. Approximately 150 animals were captured and moved from sites in the Chesapeake Basin alone. Beaver populations are increasing within the Basin.

Like the beaver, the wild turkey (*Meleagris gallopavo*) was extirpated from Delaware by the mid-1800s. In 1984, 34 wild birds were brought to Delaware from New Jersey, Vermont, and Pennsylvania. Between 1989 and 1997, 107 turkeys were captured within the state and transferred to 6 release sites in the Chesapeake Basin. Table 2.7-1 shows these release sites, the years of release, and the number of birds stocked.

Since 1990, selected turkey management zones have been surveyed for wild turkeys. Several zones have most or all of their area within the Chesapeake Basin. Due to budgetary limitations, not all zones are surveyed each year. The data collected, however, indicate increasing turkey populations in the Basin (Table 2.7-2). What appears to be a dramatic decline in Zone 16 is likely a survey anomaly since turkey-hunting data do not suggest a significant decline.

Wild turkeys are very adaptable and will use a variety of habitats from mature forests to open agricultural fields. The current mix of these habitats in the Chesapeake Basin makes the area good turkey habitat. Agricultural land provides an important winter food source in the form of waste grain. Forestland (especially forests with a significant oak component) provides food as well as nesting and roosting cover.

When Delaware residents think of Canada Geese (*Branta canadensis*), they generally think of the migratory flocks that come here from Canada in the fall. More and more, however, resident flocks that stay all year are becoming common. Resident flocks first became established in northern New Castle County, likely the result from releases of captive birds. Resident flocks are flourishing throughout the state, with approximately 500 geese using small ponds scattered throughout the Chesapeake Basin. Birds in the Basin represent approximately 15 percent of the state population.

Resident geese are becoming a problem in Delaware. In this Basin, geese have caused damage to lawns on residential and commercial properties. They litter areas with feathers and are sometimes aggressive toward humans. Trap Pond State Park has had problems with resident birds because of large amounts of droppings deposited on the public beach. There have also been complaints concerning water quality in ponds used by large numbers of birds, as well as complaints concerning crop damage to young corn and soybean plants. Because of the abundance of agriculture and small ponds, resident goose numbers are expected to increase in the Basin. To date, methods for controlling resident geese have been largely ineffective. As the human population continues to build in the Basin, goose/human conflicts will likely increase as well.

### Table 2.7-1

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### Table 2.7-2

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The previous four game species are very adaptable and are, for now, doing relatively well in the face of human impacts on the land. The northern bobwhite quail (*Colinus virginianus*) is, however, another story. This species is tied closely to, and dependent upon, early successional/grassland habitats. This type of habitat was common on the small family farms that once dotted Delaware’s landscape. However, farm hedgerows that once provided escape cover for quail have been eliminated to accommodate more crops and the large equipment used for planting and harvesting. As a rule, crops are now planted to the wood’s edge, leaving no buffer strips of grasses or weeds. In addition, today’s crop-harvesting techniques are much more efficient than they used to be. As a result, the amount of waste grain left for quail has been reduced. Finally, the use of chemical pesticides and herbicides has increased over the years. All of these factors combined have caused a drastic decline in bobwhite quail numbers.

Due to the decline in bobwhite quail populations, Fish & Wildlife implemented random statewide quail roadside survey routes in 1995. Observers count the number of quail heard whistling along a standardized route. Data are then broken down to the number of quail heard per mile driven, and comparisons are made between years. Survey data demonstrate a drop in quail numbers since 1995 (Table 2.7-3).

The decline in Chesapeake Basin quail populations appears to follow the state trend as indicated by the 1997 survey results. It is important to note however, that this Basin represents about one-third of the land area of Delaware, and includes some of the most undeveloped and unpopulated habitat. As a result, this Basin has a great potential for providing quail habitat protection and restoration. The 1996 U.S. Farm Bill presents resource managers with perhaps the last best chance to stabilize or reverse the quail decline. Congress has earmarked $2.5 billion annually for the next 10 years to fund programs that will enhance wildlife habitat and water quality, as well as reduce soil erosion. The most significant program under this bill is the Conservation Reserve Program under which farmers and other landowners can take land out of production and receive annual payments for a 10- to 15-year period. In addition, the program will cost-share up to 50 percent of the funding required to create and maintain wildlife habitat. Another program is the Wildlife Habitat Incentives Program that provides a one-time cost-share of 75 percent to landowners who would like to implement projects for wildlife.

**Non-Game Populations**

The only information people generally receive about non-game wildlife populations is about the listed (rare) species. Many animal species are not threatened with extinction. In fact, some species have even benefited from the anthropomorphic changes to the landscape over the past 300 years (e.g., red fox, gray squirrels, and woodchucks have probably never been this common). Broadspectrum habitat users such as American robins, blue jays, and ring-billed gulls have far more available habitat now than they had before the major land-clearing efforts began. Brown-headed cowbirds, killdeer, and other open-country animals have taken quite well to the man-made expansion of the agricultural “prairies” and successional forest margins. Finally, due to its ability to thrive in a variety of habitats, the coyote may quite possibly be the latest animal to be commonly observed in the Basin.

In contrast to the above “successes,” too many non-game species of animals have had their habitats reduced significantly. These animals usually have narrow habitat requirements. The critical factor to the success or failure of a species could be available breeding or nesting habitat, foraging habitat, or direct competition for habitat with exotic or native invasive species. In many cases, these vital habitats have become isolated, small, or of degraded quality. Even the best habitats are vulnerable or threatened. One example of this is a breeding colony of great blue herons (*Ardea herodias*) that has occupied an isolated portion of Blackbird State Forest for the past several years. This is one of two breeding locations discovered within the Chesapeake Basin (other rookeries have been located in Maryland). Great blue herons are intolerant of human activity near their nest location. Lack of available nesting habitat is a potential limiting factor for this species in Delaware. All but two of the Great Blue Heron colonies in Delaware are located within protected conservation lands. This is not accidental, but represents the only available nesting habitat left for this species. The Delaware Department of Agriculture, Forest Service Section (DDA, Forest Service) protects this small colony, but what must be done to ensure that the great blue heron continues to be part of Delaware’s avian fauna?

Most forest species populations are in decline in Delaware. This should not be surprising when one understands the critical factor to the success or failure of a species could be available breeding or nesting habitat, foraging habitat, or direct competition for habitat with exotic or native invasive species. In many cases, these vital habitats have become isolated, small, or of degraded quality. Even the best habitats are vulnerable or threatened. One example of this is a breeding colony of great blue herons (*Ardea herodias*) that has occupied an isolated portion of Blackbird State Forest for the past several years. This is one of two breeding locations discovered within the Chesapeake Basin (other rookeries have been located in Maryland). Great blue herons are intolerant of human activity near their nest location. Lack of available nesting habitat is a potential limiting factor for this species in Delaware. All but two of the Great Blue Heron colonies in Delaware are located within protected conservation lands. This is not accidental, but represents the only available nesting habitat left for this species. The Delaware Department of Agriculture, Forest Service Section (DDA, Forest Service) protects this small colony, but what must be done to ensure that the great blue heron continues to be part of Delaware’s avian fauna?

**Table 2.7-3**

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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Miles surveyed</td>
<td>472.5</td>
<td>465.5</td>
<td>869.0</td>
</tr>
<tr>
<td>Total whistling quail</td>
<td>785</td>
<td>464</td>
<td>468 (223)*</td>
</tr>
<tr>
<td>Whistling quail/mile surveyed</td>
<td>1.66</td>
<td>1.00</td>
<td>0.54 (0.52)*</td>
</tr>
</tbody>
</table>

(*) *results of routes within the Chesapeake Basin.
that most of Delaware’s forests have been reduced in both area, connectivity, and overall forest quality for over 300 years. Many bird species that once commonly bred in Delaware are now found infrequently or are briefly seen passing through in migration. The situation is even more troubling for the less mobile animals, fish, reptiles, amphibians, and invertebrates. The survival of these animals is critical because they represent a measure of the living resources of the state. The imperative identification and protection of natural areas that preserve this faunal diversity, which will also protect the floral diversity, is critical to keeping a healthy living resource base in the Chesapeake Basin, Delaware, and throughout the neighboring Eastern Shore.

For example, a DNHP inventory of the fauna found within the Choptank River's floodplain and surrounding upland forests revealed many species of concern for preservation. Bird species such as the Kentucky warbler (Oporornis formosus), Louisiana water thrush (Seiurus motacilla), and yellow-throated vireo (Vireo flavifrons), are migratory neo-tropical passerine species that breed in the palustrine forests of the watershed, but are rare elsewhere in the state. The cerulean warbler (Dendroica cerulea) is also dependent on mature deciduous floodplain forests and surrounding upland forests for reproductive success. Formerly present along the Choptank River, this species was not sighted during the DNHP’s latest survey. Habitat reduction may have eliminated this species from the Choptank River environs. It is now known to be breeding in fewer than six sites throughout Delaware and is faring poorly throughout its global range.

Other bird species such as the barred owl (Strix varia), red-shouldered hawk (Buteo lineatus), and pileated woodpecker (Dryocopus pileatus), are important forest predators that have disappeared from most of Delaware’s woodlands. These species require extensive tracts of mature floodplain forests to ensure successful reproduction (Clancy et al., 1995). The populations of these birds, and many others, are also in decline in Delaware because of fragmentation and elimination of the surrounding upland forests.

The high diversity of insect species, particularly odonates (dragonflies and damselflies) was found to be reflective of the variety of wetland habitats found within the study area. The most notable species found were the blue-faced meadowfly (Sympetrum ambiguum), black-water bluet (Enallagma weewa), and the blue corporal (Libellula deplanata) (Clancy et al., 1995).

In all of the Chesapeake Basin areas that have been inventoried, there are 19 aquatic animal species that have been ranked S1 (extremely rare with 5 or fewer occurrences), S2 (very rare with 6 – 20 occurrences), or SH (historically known, but not found for 15 years or more) (Delaware Natural Heritage Program Database, 1998). The list is comprised of 11 fish, 3 freshwater mussels, and 5 aquatic insects. These species, with depressed population numbers, are especially vulnerable to water-quality degradation and alterations in established food chains caused by the introduction and establishment of non-native species. Also, damming of rivers and their tributaries for millponds impedes the movement of some fish species which, in turn, impedes mussel larvae, which are dispersed by those fish.

There is a need for an inventory to determine abundance and presence of species in areas that have never been surveyed or in areas that have not been surveyed for 10+ years. Current data are incomplete regarding native minnows and freshwater mussels. Once identified, the locations of these populations need to be protected.

Although highly visible non-game species such as the bald eagle (Haliaeetus leucocephalus) have received a lot of attention, it was the protection of the bald eagle’s habitat (and the elimination of DDT use) that protected both it and perhaps thousands of other species that share the eagle's foraging territory. Ultimately, it is the protection of vital identified habitat that will preserve Delaware’s living resources and protect our biological history.

2.7.2.6 Fisheries Resources

Commercial Fisheries

The streams and rivers that drain into the Chesapeake Bay support many species of fish that are harvested for both food and profit. The majority of commercial fishing efforts take place in the Nanticoke River, with American shad (Alosa sapidissima), blueback herring (A. aestivalis), alewife (A. pseudoharengus), white catfish (Ameiurus catus), channel catfish (Ictalurus punctatus), striped bass (Morone saxatilis), and white perch (Morone americana) representing the highest percentage of the catch (Whitmore, 1997). Fishing efforts are regulated via limited entry, landing quotas, seasons, size limits, gear restrictions, and area closures. Despite these restrictions, some species have declined, are at low population levels, or at depressed historic levels. A combination of habitat loss, water-quality degradation, and overfishing has contributed to this decline (Chesapeake Bay Foundation, 1996).

Historically, the Nanticoke River was the third most productive tributary for American shad in the Chesapeake drainage (Craig Shirey, pers. comm.). Near the turn of the century, commercial landings in the Delaware portion of the Nanticoke exceeded 200,000 lbs. In the past 100 years, spawning stocks have suffered a general decline. A baywide moratorium on commercial fishing for American shad was adopted in 1980 for Maryland waters and in 1993 for Virginia waters (Dale Weinrich, Maryland DNR, pers. comm.). Harvest is still permitted in Delaware waters with no seasonal closure, size limits, or limit on the number landed.

The alewife and blueback herring, which use this drainage for spawning and nursery habitat, have also
suffered a population decline. In the Delaware portion of this drainage, there are no restoration efforts or fishing restrictions in place.

Several rivers in this Basin have been dammed to create ponds, which in turn impede anadromous species (such as alewife, blueback herring, and American shad), from reaching historic spawning areas. Below is a list of tributaries that drain into the Chesapeake Bay, and Delaware ponds that potentially impede migration through these tributaries (secondary and tertiary impediments are in parenthesis):

**Nanticoke River:**
- Collins, Concord (Fleetwood), Craigs, Williams (Hearns)

**Broad Creek:**
- Records (Trap, Raccoon, Trussum, Chipmans), Horseys, Portsville (Tussock)

**Choptank River:**
- Mud Mill Pond

The Department is currently evaluating the impact of fish ladders installed in 1996 on several Delaware Bay tributaries. Once evaluations are completed, an anadromous species management plan will be drafted. At that time, recommendations will be made regarding tributaries of the Chesapeake Bay that impede migration of anadromous species.

Yellow perch (*Perca flavescens*) populations have had a steady system-wide increase in reproduction since 1993, and the lifting of current restrictions on commercial and recreational harvest in Maryland waters is being evaluated (Paul Piovis, Maryland DNR, pers. comm.). In the Delaware portion of this drainage, there are no special restrictions and no commercial fishery for yellow perch. Minimal data exist regarding current yellow perch populations and structure.

The American eel (*Anguilla rostrata*) is a species of special concern. This species utilizes the Chesapeake Bay drainage as a nursery and feeding area. Harvested eels never have an opportunity to spawn. There is a “black market” for eels (i.e., eels less than 6 inches), which are illegally collected and sold in foreign markets for over $300/lb. The 6 – 12 inch juveniles are sold legally as bait and live food in U.S. and foreign markets. Currently, Delaware has no limit on the number of commercial licenses, no limit on the number of pots allowable per fisher, and no reporting requirements. An American eel management plan is being prepared, but minimal data exist regarding fishing effort, landings, or stock size (John Clark, F&W, pers. comm.).

**Recreational Fisheries**

Due to heavy fishing pressure on the freshwater ponds in the Basin, active fisheries management is necessary to sustain the resource and maintain recreational value. In addition, the Nanticoke River system supports the heaviest fishing pressure of all tidal streams in Delaware (Martin, 1996). The most-sought-after resident freshwater gamefish is the largemouth bass (*Micropterus salmoides*). Many fishing tournaments and man-days of fishing are directed strictly toward this species.

- Catch-and-release fishing by anglers is a major factor in preserving the quality of this fishery (Martin, 1997). Identifying and protecting spawning habitat is crucial, especially in tidal waters. Due to low recruitment into the fishery, supplemental stocking of fingerlings into the Nanticoke River has been conducted annually since 1995.

According to a 1994 angler mail survey (Martin, 1996), there was a substantial increase in projected fishing effort from 1990 – 94. The highest projected catch and effort was for the following species: largemouth bass, bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gibbosus*), black crappie (*Pomoxis nigromaculatus*), white perch, yellow perch, chain pickerel (*Esox niger*), and catfish (*Ictalurus sp.*).

The size and structure of gamefish populations in state-owned ponds are intensely monitored. The increase in fishing effort has continued, resulting in a need for more public freshwater fishing opportunities. A project to construct new ponds (less than 5 acres in size) on public lands was initiated, with construction funding available beginning in 1998.

There is a recreational gill-net fishery in this drainage, with tidal stream catch data available for each county (Whitmore, 1997). However, other than the Nanticoke River, the data are not separated by individual stream/creek. Major species targeted in these tidal areas are river herring (alewife and blueback), catfish (white and channel), white perch, striped bass, and American shad.

**Spawning/Nursery/Rearing/Feeding Habitat**

Yellow perch and golden shiners (*Notemigonus crysoleucas*) utilize submerged aquatic vegetation (SAV) for spawning and nursery areas. Other species, especially sunfish, may nest adjacent to SAV, using it as cover and as a nursery area for their offspring. It is critical that these habitats be identified and protected from degradation. Deep Creek and Gravelly Run, tributaries of the Nanticoke River, support extensive SAV beds. Siltation caused by shoreline development and destruction of shoreline buffers is a major destructive factor, killing SAV and smothering egg masses that are within the beds. Dredging and channelization projects have been proposed for some areas of the Nanticoke watershed. This type of alteration would severely affect shellfish, plant, and fish species by direct take, and by alteration of spawning, nursery, and feeding habitat.

Due to impediments that prevent upstream migration, river herring (blueback and alewife) utilize spill pools below ponds for spawning. Large spawning aggregations have been observed below Williams, Records, Craigs, and Portsville Ponds (Seagraves et al., 1990). The protection of
critical spawning habitats is important for the reproductive success of these anadromous species.

Tidal wetlands, which become inundated during high-tide conditions, are important feeding areas for predatory fish such as largemouth bass. This factor should be considered when drafting tidal wetland protection plans. The potential for bulkheading and private piers to impact or destroy the ecological integrity of these areas should also be considered before issuing permits. Some privately owned piers on the Nanticoke River transect wetlands and extend well out into the river, creating possible environmental and navigational hazards.

In areas with limited cover, dead falls and other natural debris provide protection for prey species. Mass removal of this critical ‘habitat’ could be detrimental to the populations of such species. Where possible, natural debris should be left intact.

Water quality conducive to growth, survival, and reproduction of aquatic species must be maintained or improved. Runoff of pesticides and herbicides, excess nutrients, toxic chemicals, ditching, dredging, siltation, clear-cutting for development, and loss of woodland buffers adversely affect water quality. Depending on the causative factor, aquatic species can be adversely affected during any life stage.

Water-quality degradation and subsequent eutrophication also have been linked with *Pfiesteria piscicida*, a toxic marine microorganism that can cause sudden large fish kills. This organism can persist in the environment in a dormant state, but become active when conditions are conducive to its growth and survival. It appears to thrive in nutrient-rich waters, which derive excess nutrients from various sources including runoff from lawns, golf courses, septic systems, farms, and discharge from wastewater treatment plants (DNREC and DHSS, 1997). The potential for this toxic organism to invade Delaware waters should be taken seriously. Preventive measures and efforts to curb excess nutrients should be undertaken immediately, before the organism becomes a human health risk and/or affects local fish populations.

**Lakes and Ponds**

Most ponds within the Chesapeake Basin have problems with nuisance aquatic plant growth, which in some cases is so severe that access to the pond for water-related activities is limited or even eliminated (see Table 2.7-4). The presence and spread of exotic aquatic vegetation has been documented from 1966 (Lesser, 1966) to the present (Miller, 1988). Exotic vegetation out-competes beneficial native vegetation, clogs waterways, and impedes fishing. Nutrient enrichment and subsequent water-quality degradation give exotic vegetation a competitive edge over native vegetation. The types of plants that create the most problems include several species of filamentous algae and two introduced species of submerged aquatic vegetation: hydrilla (*Hydrilla verticillata*) and cabomba (*Cabomba caroliniana*).

The Division of Fish and Wildlife (F&W) uses aquatic herbicides and an aquatic weed harvester to mitigate these problems in the public ponds. This task is carried out as requested and as resources are available. The control of excess aquatic vegetation can be expensive, costing Delaware an annual average of $40,000 – $50,000 (Miller, pers. comm.). For most years, requests for aquatic plant control overwhelm the resources available for F&W to respond. Finally, it has recently been observed that the treatment of hydrilla with herbicides is usually followed by infestations of filamentous algae — an even worse problem. This pattern needs to be further verified, but, until then, herbicide control of hydrilla should be done with extreme caution and only when absolutely necessary.

**Filamentous Algae**

Extensive floating mats of these algae are observed during the summer months on the surface of ponds throughout the state. At moderate and slight levels of infestation, filamentous algae cause little trouble for people and provide beneficial habitat for aquatic life. In extreme abundance, thick floating mats of filamentous algae have inhibited and even temporarily eliminated recreational use of Craigs Pond, Hearns Pond, and others. Other lakes that have less intense problems with this type of algae include Chipmans Pond, Horsey Pond, Records Pond, Trap Pond, and Williams Pond. Effects of heavy infestations on fish populations are unclear. For example, Hearns Pond has such a severe infestation of filamentous algae every year that residents complain for much of the summer, yet bass and bluegill fishing remains very good. On the other hand, during the month of May in most years since 1990, Hearns Pond has had a fish kill involving primarily large bluegills. Although the causes of this kill have not been positively verified, it usually coincides with the first appearance of floating filamentous algae mats and has been attributed to a combination of factors, including stress brought on by severe eutrophic conditions.

A handful of species are responsible for filamentous algae infestations in Delaware ponds including, *Pithophora, Rhizoclonium, Hydrodictyon*, and *Lyngbya*. Aquatic herbicides and mechanical harvesting are the control methods of choice. Harvesting is the only viable way to remove *Lyngbya* mats, and has the added benefit of removing nutrients from the system. All but *Lyngbya* respond well to herbicides, but there can be detrimental water-quality effects caused by the release of nutrients and oxygen-demanding substances from decaying algae. In Hearns Pond, a dense bloom of phytoplankton (blue-green algae) almost always follows herbicide treatment of algae mats. This bloom is characterized by poor water quality, including pH levels rising above 9.5, biological oxygen demand concentrations over 10.0 mg/l (acceptable concentrations are <5 mg/l) and increased murkiness of water.
Incidental or deliberate introduction of non-native aquatics can cause major problems to existing native species, fishing, other forms of water-based recreation, and water quality. Although there are numerous examples of exotic species in this drainage, several species have more potential to cause negative impacts.

Hydrilla and cabomba are introduced species of submerged aquatic vegetation (SAV). Although SAV is desirable in moderate-to-high abundance (occupying about 40 to 60 percent of the bottom and water column of a pond), these two species can cover up to 75 to 95 percent of the bottom and water column. Such extensive growth inhibits boating access and fishing effort, and can also upset predator-prey relationships that support normal growth rates and numbers of warmwater gamefish (Swingle, 1950; Cooper and Crowder, 1979; Colle, 1980; Savino and Stein, 1982; Werner et al., 1982). Ponds that have experienced problems with these plants include Chipmans Pond, Collins Pond, Concord Pond, Horseys Pond, Records Pond, Raccoon Pond, Trap Pond, Trussum Pond, and Tussock Pond.

Hydrilla and cabomba can be controlled using approved types of aquatic herbicides. Lowering the pond water level during the winter, and thereby freezing the root system, can also control cabomba. Hydrilla does not respond well to water-level drawdowns because it produces tubers, which are not as susceptible to freezing.

The control of both these plant species must be done very carefully, for there is an apparent pattern of herbicide treatments being followed by even more problematic infestations of filamentous algae and phytoplankton (blue-green algae). Despite the access problems caused by hydrilla and cabomba, water quality associated with these and other SAV species is better than that associated with filamentous algae and phytoplankton blue-green algae.

Trussum Pond, located in the eastern Broad Creek watershed, is an exception to the general rule of better water quality for ponds with SAV. An extremely dense population of cabomba has taken over this pond, as it becomes covered over with duckweed during the summer. This covering exceeds 90 percent of the entire pond’s surface from mid-June through mid-September and results in the complete exhaustion of dissolved oxygen throughout the water column. The results of fishery surveys indicate that most of the pond’s fish population has succumbed to this harsh condition. Management alternatives are contingent on replacement of the spillway because the present structure does not allow for any water-level manipulation. The pond has too many stumps and snags to allow the use of herbicides. In any event, there would be concern that the herbicides could harm the stand of bald cypress trees — the unique distinguishing characteristic of this pond. Some progress has been made toward correcting this situation, although funding sources to replace the spillway need to be identified.
Carp and Gizzard Shad

Common carp (Cyprinus carpio), a 19th-century introduction to North America from Eurasia, and the native gizzard shad (Dorosoma cepedianum) are non-game fish species. When extremely abundant, these species can upset the ecological balance in ponds. Mud Mill Pond is the only pond in the Chesapeake Basin with carp occurring in large enough numbers to potentially impact other fish species. There are no ponds in the Basin where gizzard shad are dominant, although the species is abundant in the Nanticoke River and Broad Creek. A population of carp is also known to exist in Williams Pond, but they do not appear to affect other species. There is no evidence that either of these species is a problem or represents a threat to the gamefish populations.

Grass Carp

One species that is considered an exotic, but is used as a tool for aquatic vegetation control, is the grass carp (Ctenopharyngodon idella). In Delaware, only controlled stocking of sterile triploid grass carp is permitted. The State of Maryland is concerned that this herbivorous fish may escape from Delaware ponds into the Chesapeake Bay, where they could potentially destroy beneficial aquatic vegetation. Because of this concern, a moratorium was imposed in October 1995 on the stocking of grass carp in waters that empty directly into Chesapeake tributaries.

Asiatic Clam

The Asiatic clam (Corbicula fluminea) is an exotic species that has a widespread distribution in the Chesapeake Bay drainage. It has altered ecosystem food chains, decreased diversity, and out-competed or displaced native mussel species, some of which are rare. Its tolerance of water-quality degradation gives the Asiatic clam a competitive edge over more environmentally sensitive native mussel species. Ironically, as a filter feeder, the Asiatic clam may have some beneficial effect on water quality. The significance of any such potential benefit is not known.

Zebra Mussel

The potential for zebra mussel (Dreissena polymorpha) invasion exists for some areas in the Chesapeake drainage. Environmental conditions conducive to zebra mussel survival exist in northern and central Delaware waterways, and regions along the eastern side of Chesapeake Bay (Bochenek, 1995). Zebra mussel veligers are found in the upper Susquehanna River, a major tributary to Chesapeake Bay. This discovery was one factor that led to the development of a regional policy for prevention and control of non-indigenous aquatic species found in the Chesapeake Basin (Terlizzi et al., 1995). Zebra mussels can impact water-dependent industries by clogging systems and decreasing diversity through competition with native species for food and habitat. Once established, zebra mussel populations prove difficult to control, so preventive measures need to be considered.

2.7.2.7 Living Resource Based Recreation

Delaware’s natural resources provide a variety of recreational opportunities for the state’s residents and visitors. In a 1995 statewide telephone survey conducted as a part of the state’s outdoor recreation planning process, Delawareans identified hiking and walking trails as well as historic and nature education as priority recreational needs. These needs, along with the need for boating and fishing areas and campgrounds, were desired most strongly in the Chesapeake Basin area.

Many of Delaware’s residents and visitors depend on water for their recreation enjoyment. Fishing, swimming, and boating are popular activities throughout Delaware. All of Delaware’s state parks and many local parks feature lakes, ponds, bays, rivers, or the ocean, and depend on these water bodies to draw visitors year-round. Delaware’s portion of the Chesapeake Basin includes more than a dozen publicly owned ponds and lakes, comprising nearly 700 acres, that serve recreational needs. Trap Pond State Park is a popular place for swimming, fishing, and boating, while other ponds, operated by the Division of Fish and Wildlife, are popular places for fishing and boating. Many of these ponds include boat ramps and fishing piers. The health of Delaware’s surface waters will affect the recreation potential of these lakes and streams.

Delaware’s wildlife represents a vital recreational resource base. Both consumptive recreation such as hunting, and non-consumptive recreation, such as birding, depend on the health of the state’s natural resources. The Chesapeake Basin includes three wildlife areas — Blackiston, Nanticoke, and portions of Norman G. Wilder Wildlife Areas; three nature preserves — Barnes Woods, Blackbird Delmarva Bays and James Branch Nature Preserve; and one state park — Trap Pond State Park; as well as private conservation land. In addition, the DDA Forest Service also manages important public land in the Basin, including Blackbird and Tabor State Forests, as well as the portion of Ellendale-Redden State Forest in the Nanticoke watershed. These areas include places to hunt, hike, bird-watch, camp, and enjoy nature.

Greenways

Greenways are corridors of open space that serve a variety of purposes. While the recreation and transportation components of paved greenway trails receive the bulk of public attention, undeveloped conservation greenways are important for preserving increasingly fragmented habitat, protecting stream corridors, and filtering nutrients before they reach our surface waters. Staff from Delaware’s Greenway and Trails Program work with Open Space Program staff, conservation groups, local governments, and other state agencies to promote the protection of open-space conservation corridors throughout the state. Within the Chesapeake Basin, the Broad Creek Greenway, James Branch Greenway, and Nanticoke Greenway include...
significant stream-corridor protection efforts as well as recreational opportunities.

### 2.7.3 CURRENT SOURCES OF IMPACT UPON LIVING RESOURCES

#### 2.7.3.1 Loss of Available Habitat

Baseline data for the original historic habitat in the Chesapeake Basin are not available. However, we do know that Chesapeake Basin forest acreage was lowest in the late 19th century, as the demands for pastureland, wood for construction and energy, and farmland reached its zenith. Abandonment of unproductive farms during the Depression, followed by the industrialization and urbanization of the workforce, led to a decline in the number of people working on farms. This phenomenon, coupled with the invention of the automobile and tractor, and the decreased need for wood for fuel, led to an overall increase in total forest acreage in the early 20th century. In many areas of Delaware, the suburban development and economic prosperity, which began in the middle of this century, caused these young forests to be replaced with homes, roads, retail shopping centers, and commercial areas. However, such development has largely been avoided in the Chesapeake Basin. A series of aerial photographs taken approximately every decade from 1920 until the present provide a glimpse of changes in available habitat in the Basin. The permanent loss of upland habitat, although continuing, has not increased appreciably over the past 70 years in this Basin. Changes in the quality of these remaining forests is harder to measure.

Assessments of forest cover have been conducted by the United States Department of Agriculture three times over the last 40 years, most recently in 1986. The document, *Forest Statistics for Delaware – 1972 and 1986* (Frieswyk et al., 1988), compares the last two forest inventories for each county in Delaware. Although total forest cover over this time decreased by 38,000 acres statewide, this loss was for the most part related to the urbanization of New Castle County. Sussex County lost an estimated 4,000 acres of forest during this period.

Most losses of wetland habitats in Delaware have also occurred following European settlement. Over the last 300 years, the landscape gradually has become drier due to the construction of canals, drainage ditches, and stream channelization projects to promote agriculture, shipping, and mosquito control. Dams to build millponds for water-power altered natural freshwater and tidal fluctuations, creating new anthropogenic habitats that replaced the existing natural ones. Thousands of acres of wetlands were drained throughout the state.

In the 1980s, the Department was concerned about the destruction of unique and significant exceptional wetlands in Delaware’s portion of the Chesapeake Basin. The DNHP located, mapped, and developed community classifications for these wetlands based on the community’s assemblage of rare species, geologic origins, and their distinctive physiognomic characteristics (McAvoy and Clancy, 1993). In order to convey the location, distribution, and importance of these exceptional wetlands, they were mapped and identified as Type I wetlands (e.g., bald cypress, Atlantic white cedar, coastal plain ponds).

Although Type I wetlands are considered the most unique and significant/exceptional wetlands, other wetland habitats, designated Type II wetlands, (e.g., riparian mixed hardwood wetland communities, mixed emergent communities, etc.) are also important refugia for many rare and not-so-rare native plant and animal species. An intensive biotic survey of palustrine and terrestrial habitats of Type II wetlands bordering the Choptank River confirmed the value of such wetlands. According to the DNHP, the riparian habitats associated with the Choptank include some of the finest and most diverse habitats in Kent County and are home to many species of rare plants and rare animals. The Choptank River and its associated wetlands are just one example of a high-quality riparian wetland habitat within Delaware’s portion of the Chesapeake watershed.

Wetland habitats not classified as either Type I or Type II are nonetheless also very important to biotic integrity.

#### 2.7.3.2 Fragmentation of Habitat

In addition to the loss of available habitat, the remaining habitat in the Chesapeake Basin has become increasingly splintered and isolated. Fragmentation of forest was already significant by the beginning of the 19th century, largely due to land clearing for agriculture. Today, most of the remaining forest in the Basin is found along stream bottoms and floodplains that have remained unavailable to agricultural production.

The clearing of the Chesapeake Basin forest was accomplished nearly 200 years ago and has had several effects. Some non-game animal species, which require extensive mature forests to persist, have become significantly reduced in numbers or extirpated. The remaining fragmented forest habitats contain a high ratio of “edge” as opposed to interior forests. Detrimental edge effects on the forest include increased sunlight, wind exposure, drying of soils, higher temperatures, loss of interior species, and increased vulnerability to exotic species invasion. Fragmentation favors species that prefer an open patchwork of woodlots, edges, and meadows. Examples of such species include red fox, brown-headed cowbird, raccoon (*Procyon lotor*), and white-tailed deer. These animals have become more numerous and live in closer proximity to humans than they ever have.

As the Basin’s human population increases, long-range management considerations become vital as human/pet/wild animal conflicts increase. Already, the increased
threat from zoonotic diseases (Lyme disease, hanta virus, and rabies) has caused public health concerns as animal and human populations increasingly interact.

### 2.7.3.3 Sedimentation

Accumulation of sediment in Chesapeake Basin streams has had terrible consequences for aquatic systems. Centuries of forest clearing, livestock grazing, and agriculture contributed enormous amounts of soil and gravel to both tidal and non-tidal rivers, creeks, and streams. The worst problems occurred before the 1950s. Modern soil conservation practices have greatly reduced the damage. However, there are still problems with sediment entering streams. As a result of this sediment load, fish spawning areas, which require clean sand, are destroyed. Sediment has contributed greatly to the demise of numerous species of mollusks and other filter feeders. Some historic species no longer survive in Delaware. Others have been driven close to extinction in all but the highest quality streams. Many species exist only in the protected portions of the watershed (mainly, small tributaries).

Fortunately, once sediment loads are sufficiently reduced, it is possible to achieve a higher level of stream quality, and, thereby, gradually improve stream habitat over succeeding decades. At that point, refuge populations of currently stressed aquatic species can be re-introduced. Therefore, it is crucial that we save all of the aquatic components possible. Aquatic fauna and flora must be allowed to survive in the remnants of good quality habitat that are left, so they are available for spreading diversity throughout the watershed when better conditions are established.

### 2.7.3.4 Modern Forestry

The application of silvicultural techniques has improved greatly over the last 100 years. Modern foresters develop forest management plans that effectively deal with a wide variety of conservation issues, including sediment control, game management and hunting, and passive recreational opportunities in addition to providing lumber and fiber products. Each forest management plan is tailored to the request of the landowner. These can range from maximized production of forest products by eliminating competing “non-productive” elements in the forest, to timber stand improvement and forest legacy programs. In Delaware, one result of this planning was the development of loblolly pine plantations in the southern portion of the Chesapeake Basin. These trees are actively managed by mechanical and chemical means to achieve superior forest products within a projected 40-to-50-year harvest rotation (Brown, pers. comm.). This practice has also reduced biological diversity by changing the structural and functional forest diversity. It “homogenized” the oak-pine forest.

An effort to develop “working forests” that promote biotic diversity while maintaining economic viability of forest products is currently under way (Brown, pers. comm.). However, the vast majority of forestland in the state is in private ownership and not under the management of state foresters. The DDA Forest Service directly manages less than 10,000 acres of forest. By comparison, forests owned by private forest industry total 30,000 acres. In 1986, the U.S. Forest Service estimated that private individuals owned 88 percent of Delaware’s forestland. Much of the timber on these lands is being managed without a forest management plan, essentially as it has been for 300 years. Although the total privately owned forest habitat does not appear to be decreasing significantly in the Chesapeake Basin, it typically:

- has trees less than 50 years old;
- is smaller than 100 acres in size;
- does not have a forest management plan;
- is owned by several different people;
- is too wet to clear for farmland;
- may be used as supplemental grazing for livestock;
- has been further fragmented by tax ditches; and
- provides supplemental income to the owner through hunting leases, firewood sale, or through a once-in-a-lifetime timber harvest.

Often, following the private contracted harvest of timber on these private lands, the DDA Forest Service receives complaints from landowners about how badly their forest was treated. A “working forest” management plan could avoid many of these problems if the landowner would contact the Forest Service prior to signing a contract (Brown, pers. comm.).

### 2.7.3.5 Exotic Species

A major threat to fragmented natural areas in both public and private holdings has been the introduction of numerous invasive exotic or alien species of plants and animals. Unlike most introduced exotic plant species which are benign additions to the landscape, invasive exotic plant species are overrunning forests, wetlands, open habitat, and aquatic communities. Native plant communities are in direct competition with introduced exotics. Exotic species, combined with habitat disturbance/fragmentation and an increasing population of white-tailed deer, has placed the remaining natural habitat in the Chesapeake Basin under an additional threat. At present, fewer exotic species currently threaten the Chesapeake Basin’s natural areas than in Piedmont habitats. But this is likely to change over the next few decades.

Over one-third of the species in Delaware’s flora are exotic. Several dozen species have the capability of
permanently altering habitat. To date, only the largest, oldest, most intact, or most isolated forest tracts have been able to resist exotic invasion, but even these forests are ultimately vulnerable to shade-tolerant exotic species such as Norway maple (Acer platanoides). Many sites are in grave need of exotic species control and habitat restoration.

Although the presence of exotic species is well known, very little data (other than “present/absent” designation) have been collected that documents the extent of the exotic infestation in Delaware. Invasive exotic-species issues have not been a priority with land managers, planners, or heritage databases. Meanwhile, new species of plants are being introduced into natural areas, sometimes intentionally. As the exotic plant species compete with native species for the already reduced available habitat, they do so without the threat of disease or insect herbivores that affect natives. Even deer, which eat almost anything, seem to favor the native plants over the new, unfamiliar, and/or unpalatable imported exotics.

A common event (such as the blow-down of a large tree during a thunderstorm) creates available habitat for exotic invasion, especially by vines [i.e., Asiatic bittersweet (Celastrus orbiculatus)]. Once established in sunny gaps created by the death of a mature tree, the vines smother the normal successional replacement of the fallen tree by native saplings. Clambering over the young trees, covering them with their leaves, denying them sunlight, the vines maintain an exotic tangle that native species cannot penetrate. These vine thickets are permanent. In the normal successional process, this canopy gap would return to forest eventually. Today, once the exotic vines become established, the forest cannot recover without human intervention. Instead, the vines slowly kill surrounding trees, gradually expanding the gap in an ever-widening circle.

Under these circumstances, a catastrophic storm would create the same scenario, but instantaneously and over a larger area. For decades, in most Piedmont forests, an incredible number of exotic seeds have been raining on the forest floor every year. Seedling vines have sprouted to become a significant understory component. Once an ice storm, northeaster, tornado, or hurricane strip or kill the forest canopy, these seedling vines will be able to utilize the increased nutrient load released from the dead leaves and branches left by the storm. The combination of the nutrient boost and the increased sunlight from the reduced canopy will allow the vines to permanently alter and dominate entire forests. At this point, the cost of restoration management of these forests would be enormous. An effort to protect the best natural forests must begin in the immediate future, before a catastrophic event. It is only a matter of time until this scenario becomes reality.

Major climatic storm events occur on a regular, if not predictable basis. These events are part of the abiotic processes to which all plants and animals in the region are subjected. Human alteration of habitat over the past 300 years has made some parts of the ecosystem more vulnerable and less likely to recover from future storms. Any similar event, whether natural or man-made, can potentially open the canopy to promote the spread of exotic plant species, and thereby, further degrade the remaining forests.

### 2.7.3.6 Insufficiently Protected Habitat

Protection of land in Delaware has been attempted from three different approaches: private ownership, public ownership, and regulatory protection. Of these approaches, protection via regulatory processes has been the most difficult and least successful. New Castle County protects lands to varying degrees by ordinance for lands comprising steep slopes, floodplains, and riparian buffers, water recharge areas, and land identified as Critical Natural Areas. The level of protection that is accomplished by these laws is significant, especially when compared to Kent and Sussex counties. However, the limited protection for sites not included in the state’s Natural Areas Inventory have all contributed to a continuing pattern of fragmentation and degradation of remaining habitat. Upland areas that do not fit into one of the ordinances are particularly vulnerable. Kent County has recently improved their protection efforts, particularly along riparian buffers. Opportunities to improve protection of habitat exist in all three counties, especially regarding upland forest protection.

Delaware’s lack of a Freshwater Wetlands Law has contributed to a continuing attrition of these wetlands. Ditching has also significantly altered habitat.

### 2.7.3.7 Other

Historic industrial and nonpoint pollution, including heavy metal and pesticide residues, have contributed to the degradation of Chesapeake Basin habitats, especially aquatic ecosystems. Historic spraying for mosquitoes and gypsy moths has certainly had negative effects upon the insect and avian fauna of Delaware in localized areas. Improved pest management techniques have reduced this impact. In-depth discussions of these issues are contained elsewhere within this document.

### 2.7.4 POSITIVE INITIATIVES

#### 2.7.4.1 Protection of Habitat

In 1973, the Delaware Nature Education Center, Inc. (now Delaware Nature Society) brought together 25 experts in their respective fields to identify the most important natural areas in Delaware. Led by the project director Norman G. Wilder and principal author Lorraine M. Fleming, the culmination of this effort was the 1978 publication of *Delaware’s Outstanding Natural Areas and Their Preservation*. *
The State of Delaware enacted Title 7, *Delaware Code*, Chapter 73: Natural Areas Preservation System, on February 10, 1978. This legislation and the subsequent regulations that were passed provided the State of Delaware, through the Department, the ability to dedicate public and private nature preserves, identify and maintain a statewide Natural Areas Inventory, and establish a Natural Areas Advisory Council to review and make recommendations to the Department Secretary. One of the first nature preserves, Barnes Woods, was established in 1984 in the Nanticoke River watershed.

The definition of a *natural area* is an area “of land or water or both land and water, whether in public or private ownership, which either retains or has re-established its natural character (although it need not be undisturbed), or has unusual flora or fauna, or has biotic, geological, scenic or archaeological features of scientific or educational value” (Natural Areas Preservation System, Title 7, *Delaware Code*, Chapter 73). Natural character refers to the native plant and animal species and associations that occupied Delaware under the influence of Native North Americans at the time of European occupation.

The following are examples of the major programs conducted by the Lands Preservation Office of the Division of Parks and Recreation.

*The Natural Areas Inventory*

The Natural Areas Inventory has identified 12 natural areas (out of the 67 identified in the state) within, or partially within, the Chesapeake Basin (see Map 2.7-1 Living Resources). A previously digitized GIS layer for the inventory is currently being compared with DNHP element occurrences. The finished maps will form the basis of a Natural Areas Directory, which will be used as a planning document to help protect Delaware’s dwindling natural areas. Once the directory is completed and distributed to interested parties, the task will shift toward updating the inventory by identifying and adding qualified new areas previously excluded, and deleting areas recently destroyed. The Natural Areas Advisory Council must vote to amend the inventory before any changes can be made. Updates of the directory will be sent to the recipients of the first edition. It is hoped that the directory will facilitate the protection of some of Delaware’s most important natural areas. Currently, protection of natural areas is voluntary, except in New Castle County. There, the owner, prior to the county’s acceptance of any development plan, must produce a Critical Natural Areas Report. Even in this case, the ultimate decision on whether to protect a natural area or not is New Castle County’s and not the state’s.

In selecting a state-recognized natural area, the Office of Nature Preserves, in conjunction with the Natural Areas Advisory Council, evaluates a site based on the following non-prioritized criteria: representativeness; biological rarity; uniqueness; diversity; size; viability; defensibility; research, education, or scenic value; and outstanding geological, archaeological, or aquatic features. Sites can be added or deleted from the inventory.

The Natural Areas Inventory was not intended to include every natural area remaining in Delaware. The intent was to include only the areas that were of statewide significance. As a result, many areas that meet the criteria were not included in the inventory. During the 19 intervening years since the inventory was established, a tremendous amount of suburban expansion has taken place in Delaware. Lands formerly considered marginal for housing purposes are being developed today. Areas not currently included on the inventory are being reconsidered for inclusion. Among the concerns and priorities of this review is providing adequate upland buffer to wetlands and stream and river corridors, and protecting the larger isolated upland forest patches and rare habitats scattered throughout the region.

New Castle County’s new Unified Development Code (UDC) provides protection for lands within New Castle County that have been listed on the state’s Natural Areas Inventory. The UDC refers to lands on the inventory as “Critical Natural Areas.” County planners work closely with the Office of Nature Preserves and private landowners to coordinate protection of these identified natural areas. The UDC also offers varying amounts of protection for steep slopes, riparian buffers, and floodplains, and provides the only non-voluntary state or local protection of privately held natural areas within the Chesapeake Drainage Basin.

*State Nature Preserves*

Three of the 19 dedicated State Nature Preserves are within the Chesapeake Basin: Blackbird Delmarva Bays, Barnes Woods, and the James Branch. These locations are depicted on Map 2.7-1 Living Resources. Natural Area Protection Plans are being developed to maintain the natural conditions that merited the original dedication of these preserves. Numerous other possible additions to the preserve program exist within the Basin. Nature preserve dedication is the highest legal protection available within the state, requiring the concurrence of the governor and the legislature to remove or “deactivate” a nature preserve.

*State Resource Areas*

Lands purchased by local and state government is the latest and perhaps the most important step in providing protection for areas that contain significant habitat. Thousands of acres scattered across the watershed are now owned by public agencies (see Map 2.7-1 Living Resources). Significant habitat remains on these properties.

The State of Delaware has acquired land through various programs for recreational benefit and natural resource
protection. The State of Delaware enacted Title 7, Delaware Code, Chapter 75: Delaware Land Protection Act, on July 13, 1990. Perhaps better known as the “Open Space Program,” the initial funding for this program was provided by the sale of bonds. In 1990, the Open Space Program, administered by the Division of Parks and Recreation’s Land Preservation Office, continued a systematic approach to land acquisition that had begun with the Governor’s Land Acquisition Program established in 1987.

Twenty regions in the state identified as State Resource Areas (SRAs) encompass a total of 250,000 acres. These SRAs include protected state, federal, local, and private conservation lands and inholdings, as well as potential additions to these areas (approximately 125,000 acres). These lands are protected through a variety of means, including purchase, donation, and conservation easements. Forty-seven-million dollars of open-space funding (plus $9 million from other sources) had been spent for land acquisition in these SRAs as of May 1, 1996. These monies acquired 13,175.4 acres valued at $84 million dollars.

SRAs within the Chesapeake Basin include Nanticoke River, James Branch, parts of Chesapeake and Delaware Canal, the Blackbird and the Great Cypress Swamp SRAs, as well as most of Ellendale/Redden and Central Kent County SRAs (which includes Norman G. Wilder Wildlife Area). It also includes the Tabor State Forest, which is considered a stand-alone area not located within an identified SRA.

From 1990–1997, the acquisition of 4,272 acres of land within the Chesapeake Basin, for a total net cost of $4,859,900 (including $385,600 in federal match grants via F&W), reflects the relatively low cost of land acquisition in this Basin. The average per acre cost was $1,047. However, this does not reflect the cost of maintaining these properties for the managing agencies.

**Farmland Preservation**

The Department of Agriculture has been leading the effort to preserve farmland by establishing Agricultural Districts and purchasing development rights to critical farmland throughout Delaware. Because many farms contain some natural areas, the purchase of development rights offers protection for these areas as part of the overall “working farm.” Map 2.2-4 Agricultural Preservation Districts shows the lands currently covered under this program.

**Private Conservation Organizations**

Significant habitats within the Chesapeake Basin have been acquired by two important non-profit organizations: Delaware Wild Lands, Inc., and The Nature Conservancy. Delaware Wild Lands’ record of land conservation in Delaware began in Chesapeake Basin with the acquisition of Trussum Pond. Later acquisitions preserved a major portion of the forested riparian habitat along the James Branch. Delaware Wild Lands acquired perhaps the most important natural habitat in Delaware, the Great Cypress Swamp, in the 1970s when a major portion of the property was threatened with development. This 10,000-acre property has been responsibly managed by this organization for over 20 years. The Pocomoke River drains the western portion of the Great Cypress Swamp to Chesapeake Bay.

The Delaware Chapter of The Nature Conservancy has been very active in recent years working with landowners and acquiring significant natural areas in the Middleford North area along the upper drainage of the Nanticoke River north of Seafood.

**2.7.5 Trends**

An undeniable fact within the Chesapeake Basin is that the species composition of the remaining natural areas has permanently changed. The 18th-century direct habitat conversion of natural areas to agricultural use has altered a functioning natural landscape into a sprinkling of isolated islands and ribbons of natural areas in a sea of agricultural fields. Add to this the introduction of alien species, pollution, excessive sedimentation, altering of natural waterways, etc., and each natural area is further eroded. In addition to species loss from these direct impacts, the theories of island biogeography have shown that, in general, as landscape patches become smaller and more isolated, they can each sustain a diminished number of species over time (Harris, 1984). In sum, direct loss and degradation of habitat, as well as the loss of connectivity between habitats, has resulted in a significant loss of species diversity within our natural areas.

A number of bird species are experiencing local, regional, and, for some, global declines. The taxa most affected are those which depend upon pristine, forest-interior habitats, as well as insectivorous species and ground-nesting species (Davis, 1996). There are a number of local and regional factors, in addition to direct habitat loss, which are thought to contribute to their decline. One likely factor is the loss of structural diversity within forests. This loss, in turn, is due in part to over-grazing by white-tailed deer and livestock, modern forest management practices, and the desire for “clean” forests in areas directly managed by people. An additional factor is the explosion in feral cat populations. In many areas, these “super hunters” are present at densities far beyond natural predator densities, and are taking a disproportionate toll on songbird populations (Frink, 1996).

With the exception of fish, freshwater macroinvertebrate species, and game species, little is known of the current status of animal populations and their distribution in the Chesapeake Basin. Several other animal groups, including birds, reptiles, amphibians, and some insects (butterflies) have been sporadically sampled throughout the region. Of the animals and plants that are listed by the Delaware Natural Heritage Program (1998) as species of concern,
many are found exclusively in Chesapeake Basin habitats. Generally, the more secretive the animal, the less is known about it. Basically, if more habitats can be protected, both in diversity, connectivity, and size, then the greatest number of species of plants and animals will be able to survive in Delaware.

While many native species have been lost, or severely reduced, others are increasing in number. Species increasing in number include raccoons, opossums, American Robins, resident Canada geese, rock doves, and brown-headed cowbirds. These are adaptable, "broad-niche" species, which can tolerate or even thrive on living in a human-dominated, suburbanized landscape. While they may represent "wildlife" to many people, their ubiquity is in many ways an indication of just how unbalanced our natural systems are becoming.

### 2.7.6 INFORMATION NEEDS

In compiling the information for this assessment, one is overwhelmed with how little is known and how little effort has been made to pull together diverse sources of information. Some of the state’s most valuable natural lands are located in this Basin. Many of these are still intact because most growth has occurred in other areas of the state. Although, the Department and other non-profit organizations may try to protect these natural lands, the scarcity of data and the lack of a coordinated analysis prohibit any comprehensive protective approaches. The following recommendations highlight some of the major data gaps and information needs.

### 2.7.7 DATA GAPS AND RECOMMENDATIONS

1. Upland forests have been almost eliminated from the majority of the landscape, limited to floodplain borders, or isolated patches in palustrine forest. What remains continues to decline and degrade because of repeated disturbance. **Recommendation:** A survey of the Chesapeake Basin should be conducted as soon as possible to identify remaining upland forests and to evaluate the quality of these areas using such factors as biodiversity, size, age, and exotic infestation. Appropriate actions should then follow such as landowner contact, natural area designation for qualifying tracts, legal protection, and/or restoration. “Reference forests” should be established on public or private conservation lands to provide management baselines.

2. Some rare habitat types may be in danger of disappearing completely from the Delaware portion of the Chesapeake Basin. **Recommendation:** A survey of such habitats should be conducted and summarized. Appropriate actions should be taken to protect these areas, including natural area designation for qualifying tracts, landowner contact, legal protection, and/or restoration.

3. Establish guidelines for protection of these resources in each county Comprehensive Plan. **Recommendation:** To varying degrees, each Comprehensive Plan has already incorporated some of the ideas put forward in this document. A dedicated effort to improve and enforce the plans must be made in the future to prevent further degradation of natural resources.

4. Identify and educate private forest owners regarding wildlife habitat, biodiversity maintenance, and the establishment of long-range goals to achieve acceptance of multiple-use land management objectives.

5. The majority of our most critical living resources are dependent upon good quality aquatic habitats as well as a natural flooding regime. **Recommendation:** Promote activities which eliminate unnaturally high sedimentation and erosion rates, and unnaturally high nutrient inputs. Assess the effect of direct stream irrigation on aquatic and riparian systems.

6. One of the most significant impacts on our environment comes from the direct and indirect effects of new construction in areas more and more peripheral to existing urban areas, schools, and employment centers. **Recommendation:** When and where construction is needed, encourage infill to existing developed areas rather than development of “green” spaces. Encourage the placement of trails and other recreation amenities away from sensitive natural areas not suitable for recreation. Continue to work with communities to encourage the protection of stream corridors.

7. Resident geese are becoming a nuisance. Their numbers have been increasing annually in the Basin, and are problematic due to their feces and feather residues, eutrophication of the lakes and streams where they reside, and aggression toward some humans. **Recommendation:** Encourage stream and pond management that incorporates wide buffers of natural vegetation, including stands of woody species when possible.

8. Develop a uniform approach toward the management of aquatic weeds that does not allow for the degradation of our ponds into dead-end filamentous algae pools. **Recommendation:** Examine current management approaches and develop a more effective, broad-based management approach. Educate pond managers and concerned public with the issues regarding the eutrophication problem in ponds.

9. Recognition of the threat of invasive plant and animal species to the Chesapeake Basin drainage. **Recommendation:** Discourage planting invasive plants in Delaware. Discourage introduction of invasive animals to Delaware. Encourage the use of native and non-aggressive exotic plant species. Train management personnel to recognize invasive species and to develop management strategies. Make this information available to local citizens.
10. The lack of fire during the 20th century in the Delaware upland landscape has had a negative effect on the fire-dependent plant and animal species across the state. **Recommendation:** A test-scale controlled burn should be conducted on fire-dependent plant communities to re-establish the link between fire and the natural diversity and adaptability of the extant species in Delaware’s modern forests and marshes. This should be done under the lead auspices of the DDA Forestry Service. The tests could be attempted upon DNREC and/or DDA lands.

11. There is a lack of data regarding the status of the American eel (*Anguilla rostrata*) population. While the harvest of elvers (less than 6 inches) is illegal in Delaware, there is a legal commercial fishery for subadults (6–12 inches). Currently, there is no limit on the number of commercial licenses that can be issued, no limit on the number of pots allowable per fisher, and no reporting requirements. **Recommendation:** Mandatory reporting requirements are needed to determine the status of the fishery.

12. The American shad is an anadromous fish that breeds in Delaware rivers and streams. The numbers of shad remaining are low compared to historic populations. **Recommendation:** Implement American shad restoration and protection projects including the construction of fish-passage facilities, development of a hatchery program, and limiting existing harvests to allow for the population to reach sustainable harvest levels.

13. Recreational fisheries need to be protected from water quality and habitat degradation resulting from accelerated development. **Recommendation:** Maintain or establish “no wake” zones where needed. Boat wakes can cause siltation and wave action detrimental to submerged aquatic vegetation (SAV). The use of non-structural alternatives for erosion control or a combination of rip-rap with natural vegetation should be emphasized where shoreline erosion is a problem for property owners.

14. Prohibit dredging in the Nanticoke upstream of Rte. 13 in Seaford. Siltation and mechanical removal of benthic sediments would disrupt SAV beds, freshwater fish, wetland plants, shoreline vegetation, and benthic invertebrates. Secondary impacts associated with a resulting increase in boat traffic could have a detrimental effect on overall water quality. Dredging would also eliminate much in-stream structure so attractive to largemouth bass. Critical spawning habitat in the Nanticoke River should be identified through subaqueous mapping and available fish-sampling data. Once identified, these areas should be afforded protection from excess siltation, dredging, and water-quality degradation.

15. Freshwater mussel surveys designed to determine distribution, age structure, and density of the populations is ongoing. However, there is currently no protection afforded those areas with high quality mussel populations. **Recommendation:** Once high-quality freshwater mussel sites have been identified, they should be afforded protection from habitat degradation.

16. If it has not been initiated already, a plan needs to be developed regarding how to prevent zebra mussels from becoming established in Delaware (educating anglers, boaters, etc.). Veligers have been found in the upper Susquehanna, and it is probably a matter of time before they arrive closer to Delaware.

17. Facilitate the Department’s Conservation Reserve Program and Conservation Reserve Enhancement Program efforts to provide matching funding to landowners to restore habitat.

18. Incorporate Delaware Natural Heritage Program databases with other planning databases, including those in Maryland, so that rare species are identified prior to development.

19. Identify restoration possibilities to increase connectivity between available habitats (include cooperative opportunities with Maryland).

20. Little information is known about the status of many native fishes (mostly non-game species). More data need to be collected on the presence and population levels of these native species.

21. There is a need for data collection pertaining to yellow perch. There are no data available on spawning locations, spawning success, population structure, and population levels.

**2.7.8 REFERENCES**


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2.8 LAND-USE ANALYSIS

2.8.1 URBAN GROWTH AREAS

2.8.1.1 Definition

An urban growth area is a defined area of land having primarily urban land uses designated to be the main focus of future growth. Urban growth boundaries are usually established by one or more governing bodies that have jurisdiction over the defined area. Generally, such areas are already urban in nature and often have an incorporated town or city as its core. As such, a growth boundary usually contains the region's economic and cultural assets. On the outside of a growth area, there is often mostly open land comprised of farmland, forests, and natural wetlands, and only scattered settlements.

2.8.1.2 Location

The Chesapeake Basin has six complete designated urban growth areas: Bridgeville, Delmar, Greenwood, Laurel, Seaford, and Blades. Western Georgetown, Ellendale, and Harrington growth areas are also in the Basin. All are located in Sussex County, except for a small portion of the Harrington growth area in Kent County. Map 2.2-5 State Investment Areas shows the boundaries of these urban growth areas.

New Castle County

The minimal portion of New Castle County in the Chesapeake Basin is projected to become developed into suburban uses within the next 20–40 years. This region can be divided into three distinct areas.

- North of the canal, the land is partially sewered with the exception of areas west of Iron Hill and west of Frazer Road. This land is zoned for medium-density suburban uses on public sewer systems. The county's first priority for allocating unused sewer capacity is to infill areas easily served by existing sewer districts. Areas that are not sewered and areas that cannot be sewered with gravity systems are not planned for additional sewer investment.

- South of the canal and to the west of Middletown is the location of a proposed new county sewer district. Bunker Hill Road is generally the north-south divide. This land, if already subdivided for septic or community systems, is zoned as residential under the Neighborhood Conservation (NC) classification, or if public sewer is anticipated it is classified as Suburban (S). Some developers may also consider privately owned spray irrigation systems, which could transferred to county jurisdiction when regional sewer becomes available. Operating land application facilities may be retained by the county to supplement...
the capacity of the Middletown-Odessa-Townsend (M-O-T) regional treatment works. New subdivisions will have dry pipes installed to facilitate hooking up when central sewer becomes available. In the S zones, 20,000-square-foot lots are allowed if 35 percent open space is set aside and a 10-acre minimum subdivision is created (in the spirit of the superseded Cluster Option). To obtain a county Certificate of Occupancy, a sliding scale impact fee for sewer applies in this area’s planned new sewer district.

- South of Bunker Hill Road to the county line, the remaining areas are classified as Suburban Reserve (SR), which requires 5 acres per lot on a septic system. The land in this portion of the Basin is presently utilized almost exclusively for agriculture and woodlands. The intent of the SR is to maintain low density to deal with environmental constraints or until the SR areas and Middletown areas are built out in 15–20 years. “Open Space Subdivisions” with community waste water system are permitted in the SR zone with 60 percent open space set aside and a minimum of 20 acres.

**Kent County**

The portion of Kent County in the Chesapeake Basin has no designated growth areas. The area is almost entirely rural in character. The communities of Hartly and Marydel have experienced minimal growth over the past 30 years and are not designated by county government as an urban growth area.

Kent County has designated the Route 1, north-south transportation corridor, with its associated sewer and water infrastructure, as a “build-out” area. The county is encouraging growth in this area, which is 2 miles from a sewer pumping station. In encouraging growth in this area, this policy lessens growth pressure in other areas of the county, including the Chesapeake Basin area west of this growth area. The west Harrington area has little development, but is within 2 miles of the county’s sewer pumping station.

The Sewage Treatment Plant in Harrington is on the east side of town and discharges into Brown’s Branch, which flows northeastward into the Murderkill River. Most of the land 2 miles north of Harrington and west of Route 13 is utilized for corn and soybean production, with some livestock operations.

**Sussex County**

The Sussex County portion of the Chesapeake Basin contains six whole designated growth areas and portions of two others. The communities of Laurel, Blades, Seaford, Greenwood, Bridgeville, and Delmar are the cores of urban growth areas. Also, portions of the Georgetown and Ellendale growth areas reside in the Chesapeake Basin. The county government established these growth areas in conjunction with the towns through the county’s comprehensive land-use planning effort of 1996–97. These designated growth areas are governed by the municipalities in the incorporated center core and the county government in the outer unincorporated areas of the boundary. An estimated 17,000 citizens, or 36 percent of Sussex County’s portion of the Chesapeake Basin residents, live within a designated growth area.

During the Preliminary Assessment phase of this Basin’s review, the “Western Sussex Water and Sewer Plan” was completed and accepted by Sussex County. The plan, developed by Whitman, Requardt and Associates (WR&A), identified the existing Water and Sewer infrastructure available along the U.S. Route 13 corridor. Specifically, the plan examined the water and sewer infrastructure needs for Greenwood, Bridgeville, Seaford, Blades, Laurel, and Delmar. The period of study is from a base year of 1995 to future projections in the year 2020 (see Table 2.8-1 Wastewater Flow Projections). Population growth rates were from the Delaware Population Consortium. During the study period, these growth rates indicate that 35 percent of the overall population increase in Sussex County will occur in western Sussex County.

**Table 2.8-1**

**WASTEWATER FLOW PROJECTIONS**

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<tr>
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<td>385,000</td>
<td>521,000</td>
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<td>991,000</td>
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<td>847,000</td>
<td>935,000</td>
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WR&A came to the following conclusions:

- Based on water-demand projections, all towns in the study area will have to upgrade their existing Department well-withdrawl permits by 2020. The towns of Blades and Delmar will have to upgrade their safe well-pumping capacities and Greenwood, Bridgeville, and Blades will require additional storage.

- WR&A recommends that all these towns begin developing surface-water protection areas to protect their ground-water supplies.

- All wastewater systems in the study area will require infrastructure upgrades to serve areas in their respective development districts. The plan refers to the “development districts” as those areas consisting of towns, town centers, and development districts as defined in the 1997 Sussex County Comprehensive Plan.

- The study found that the service areas of Seaford, Blades, Laurel, and Delmar will have wastewater treatment capacity shortfalls of 780,000; 640,000; and 200,000 gallons per day respectively by the year 2020.

The plan summarizes the costs required to serve the projected growth area (refer to Table 2.8-2 Capital Cost Projections), as defined by Sussex County. These costs include both upgrading and replacing existing infrastructure, as well as the construction of new facilities to serve areas in the development districts. Costs for the Blades Sanitary Sewer District reflect the infrastructure and treatment necessary to serve the expanded district.

The report contains several conclusions and recommendations pertinent to this Basin report, as seen below:

- Individual towns should provide sanitary sewer service to designated growth areas. (Note: The state does not necessarily concur or agree with the size or shape of these designated growth areas.)

- New subdivisions in designated growth areas should be directed to connect to the appropriate central sewer system for the towns along the Route 13 corridor.

- Towns should manage growth within their incorporated boundaries and monitor growth in their development districts. Preliminary engineering studies should be conducted to verify available system capacity and the infrastructure required prior to implementing future projects.

- Once funding is available, towns should look at establishing sewer or water protection areas to safeguard water supplies.

- The Town of Bridgeville should continue nitrogen sampling and upgrade biological treatment capacity to 800,000 gallons per day.

- A regional wastewater treatment plant to serve the Blades Sanitary Sewer District Planning Area, Laurel, and possibly Bethel should be reconsidered within the next five years.

2.8.1.3 Relationship to Natural Resources

Urban growth areas exhibit severe environmental impacts on-site and varying impacts downstream. In general, little natural, undisturbed habitat is retained in an urban growth area. A community park may be the occasional exception. However, by definition, the urban-growth portion of the Chesapeake Basin is expected, and even encouraged, to urbanize. In theory, the growth or urbanization of this land in an urban growth area will spare natural and agricultural lands in the more rural areas outside the growth area.

Infrastructure within growth boundaries generally keeps pace with new urban growth within the growth

### Table 2.8-2
CAPITAL COST PROJECTIONS

<table>
<thead>
<tr>
<th>SERVICE AREA</th>
<th>COLLECTION &amp; CONVEYANCE</th>
<th>LIFT &amp; PUMP STATIONS</th>
<th>TREATMENT</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridgeville</td>
<td>$ 4.59 M</td>
<td>$ 0.83 M</td>
<td>$ 0.48 M</td>
<td>$ 5.9 M</td>
</tr>
<tr>
<td>(including Greenwood)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seaford</td>
<td>$ 6.1 M</td>
<td>$ 0.6 M</td>
<td>*</td>
<td>$ 6.7 M</td>
</tr>
<tr>
<td>Blades</td>
<td>$ 8.8 M</td>
<td>$ 1.0 M</td>
<td>$ 5.9 M</td>
<td>$ 15.7 M</td>
</tr>
<tr>
<td>Laurel</td>
<td>$ 5.75 M</td>
<td>$ 0.9 M</td>
<td>$ 0.85 M</td>
<td>$ 7.5 M</td>
</tr>
<tr>
<td>Delmar</td>
<td>$ 4.59 M</td>
<td>$ 0.65 M</td>
<td>$ 0.69 M</td>
<td>$ 5.9 M</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$ 29.8 M</td>
<td>$ 3.98 M</td>
<td>$ 7.92 M</td>
<td>$ 41.7 M</td>
</tr>
</tbody>
</table>

*Seaford Plant upgrade and expansion under construction.*
boundary. Sewer systems and public water systems are frequently required as new growth occurs. Problems arise as local (and usually old) sewage treatment plants reach capacity as additional wastewater is collected from the new urban growth areas. Public water-supply systems may encounter similar problems as demand for water outpaces the municipal well's ability to pump and deliver potable water.

Most of the land has been developed for urban and suburban uses (such as residential, commercial, and industrial use) with considerable land tied up in publicly owned infrastructure such as roads, schools, and streets. Perhaps less obvious than the lack of natural habitat is the growth area's potential to generate urban storm-water runoff. This runoff is a form of nonpoint source pollution which occurs after significant rainfall. Rain and snowmelt run off the impervious surfaces (roofs, streets, parking lots, etc.) to local waterways, carrying with them contaminants such as motor oil, road salt, lawn fertilizer, and herbicides, bacteria, and common litter. Sediment from construction sites may also be in the runoff.

Streambank erosion is generally minor in this Basin due to the overall slow flow of the Basin's streams. Also, wetlands and/or aquatic vegetation in and immediately adjacent to streams minimize erosion. The area has a flat topography that is not conducive to significant overland water flow, which would otherwise erode streambank soils.

Flash-flood potential is extremely minor in the Chesa-peake Basin due to the level topography and sandy soils. Rainfall percolates into the soil or slowly drains off the land in a harmless fashion. Ponding of rainwater on streets and highways does occur, however, and can pose a road hazard. Ponding may also impede farmers from tending their fields as low spots fill with water after unusually intense rains.

Wetlands within the growth areas are often degraded to varying degrees in many locales due to the poor water-quality characteristics of urban nonpoint source pollution.

### 2.8.1.4 Infrastructure within Growth Boundaries

Many of the residences and businesses within the growth area boundaries are connected to municipal sewage treatment plants, and are served by public water. These same growth areas also offer solid waste collection services for nearly all residents and businesses by the anchor municipality or private trash haulers.

The Cabinet Committee on State Planning Issues has already suggested that steps be taken to:

- “Encourage investment policies for the provision of water and wastewater infrastructure which strengthens communities, fosters more compact development patterns, and promotes the preservation of farmlands and open space.”
- “Discourage the extension of public water and sewer service which promotes development in open spaces and natural areas.”
- “Encourage redevelopment and improve livability of existing communities and urban areas.”
- “Direct state investment and future development to existing communities, urban concentrations, and designated growth areas.”

### 2.8.1.5 Intensity of Growth Areas

The Laurel growth area has the highest population density, with an estimated 393 persons per square mile. The Delmar urban growth area is least developed and has ample open space for new development. Table 2.8-3 lists densities based on data available from the most recent census report and comparison of growth areas as seen in the “1997 Sussex County Comprehensive Plan, Final Draft, March 10, 1997.”

The pattern of development in the Basin has historically relied on centers of transportation to get agricultural produce to markets in Wilmington, Philadelphia, and Baltimore. Many of the communities in the Basin sprang up along railroad depots. This is particularly so for Bridgeville, Greenwood, Seaforth, Laurel, and Georgetown. Seaforth area residents also utilized the Nanticoke River to ship by water. This river is still used today for interstate shipping of oil products, grain, and materials for the DuPont Company. Currently, the growth centers utilize the railroad for moving bulk products in

<table>
<thead>
<tr>
<th>GROWTH AREA</th>
<th>ESTIMATED POPULATION</th>
<th>SIZE OF GROWTH AREA (SQ. MI.)</th>
<th>POPULATION DENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenwood</td>
<td>694</td>
<td>2</td>
<td>347</td>
</tr>
<tr>
<td>Seaforth</td>
<td>7,040</td>
<td>18</td>
<td>389</td>
</tr>
<tr>
<td>Bridgeville</td>
<td>1,459</td>
<td>5</td>
<td>291</td>
</tr>
<tr>
<td>Laurel</td>
<td>3,928</td>
<td>10</td>
<td>393</td>
</tr>
<tr>
<td>Delmar (Del.)</td>
<td>1,141</td>
<td>8</td>
<td>143</td>
</tr>
<tr>
<td>Georgetown (1/4)</td>
<td>1,100</td>
<td>6</td>
<td>183</td>
</tr>
<tr>
<td>Ellendale (1/8)</td>
<td>380</td>
<td>2</td>
<td>190</td>
</tr>
</tbody>
</table>

Note: Figures are from the 1996 census population estimate, plus 10% for unincorporated development in growth areas.
and out of the Basin. Importing fertilizer for the farming community and exporting their grains to mills outside the Basin is of special importance. Highways now carry many items the trains once moved. These highways are now at least as important as the railroad in moving products.

### 2.8.2 NON-GOVERNMENT ORGANIZATIONS

The Nanticoke River watershed (including the Marshyhope Creek) comprises the single largest river system in the study area and in the state. Not surprisingly, it has several private local environmental organizations monitoring the activities on and around the river. Also, there are numerous national organizations that have local interests in the Chesapeake Basin, such as the Sierra Club and the Audubon Society. Discussed below are five of the more active private organizations in the Chesapeake Basin. All are mainly concerned with the Nanticoke River system in Delaware and Maryland.

#### 2.8.2.1 Nanticoke Watershed Alliance

The Nanticoke Watershed Alliance consists of private non-profit organizations, businesses, trade associations, and public agencies from Maryland and Delaware. Their main mission is to examine and advocate conservation strategies for the Nanticoke Watershed. The alliance is led by a board of directors comprised of representatives from the Nanticoke Watershed Protection Committee, the Wicomico Environmental Trust, and Friends of the Nanticoke.

#### 2.8.2.2 Nanticoke Watershed Preservation Committee

The adopted purpose of this citizen organization is “To recognize the Nanticoke River watershed as a priceless natural resource that must be cherished and passed on to future generations.” The group has adopted goals to deal with development in the watershed, environmental issues, recreation and open space, and education for continued awareness.

#### 2.8.2.3 Nanticoke River Watershed Conservancy

This conservancy was established to promote the preservation, protection, and balanced use of natural resources principally in, but not limited to, the watershed of the Nanticoke River and its tributaries. This organization is also interested in the acquisition and holding of conservation easements and other real property issues. Thus, the conservancy’s main interest is that of land protection.

#### 2.8.2.4 Chesapeake Bay Foundation

This foundation is the largest non-profit conservation organization working to help restore the Chesapeake Bay. The foundation was established in 1967 and has 85,000 members and contributors from corporations and from philanthropic foundations. Areas of special interest for this foundation include land-use planning, education, water quality, habitat, and transportation.

#### 2.8.2.5 Delmarva Water Transport Committee

This committee is comprised of public agencies and private businesses interested in maintaining a navigable channel in the Nanticoke River. Membership includes the DuPont Company, Cargill, and the U.S. Corps of Army Engineers (Baltimore District).

### 2.8.3 LAND-USE REGULATIONS

#### 2.8.3.1 Subdivision Procedures

The Department has regulatory program requirements for erosion and sediment control, wetlands, subaqueous lands, water supply, wastewater, air pollution control, and other environmental issues that must be met by all new developments. Some departmental programs provide a baseline, or minimum set of environmental standards. The Department, through its review and comment on Delaware Land Use Planning Act (LUPA) reviews, Subdivision Reviews, and Developers Advisory Service Reviews encourages people, through incentives and environmental information, to exceed these minimum standards.

Local governments with land-use regulatory powers such as the counties derive those powers from County Planning. In addition, Middletown, Marydel, Greenwood, Bridgeville, Georgetown, Seaford, Delmar, Ellendale, and Laurel also derive local land-use powers from their town charters, each of which are individually crafted and approved by the General Assembly. Infrequently, applicants have great difficulty meeting local land-use standards and are granted a variance from local land-use regulations after a public hearing.

New Castle, Kent, and Sussex counties send all land-use planning action applications they review to the Office of State Planning Coordination for possible selection for review and comment under the state Land Use Planning Act (LUPA). LUPA review projects. Comments are available on the Office of State Planning Coordination’s Internet site (http://www.state.de.us/planning).

#### New Castle County

In New Castle County, a Unified Development Code (UDC) is used to combine the functions of the now
superseded Zoning Ordinance and Subdivision Regulations. The old Zoning Ordinance regulated uses in zones and rezonings, and the Subdivision Regulations regulated new major and minor subdivisions.

Under the UDC, new development will be subject to performance standards, including community character, more stringent environmental standards, and adequate public facilities. A major benefit of the UDC is that it provides predictability through requiring site plans to be submitted with rezonings. Additionally, existing zones are designated through measures of existing community character. The UDC will limit the growth of strip development by combining highway access in adjacent newly created lots and through stimulating open space development that requires 60 percent open space in SR Zones with a 20-acre minimum, or one septic system for every 5 acres.

**Kent County**

Kent County has separate Zoning and Subdivision Ordinances. The Zoning Ordinance refers to the zoning requirements and regulations such as setbacks and separation between incompatible uses. Kent County’s Zoning Maps show the boundaries and labels of the zones into which the county has been divided. The Subdivision Ordinance requires mapping of the metes and bounds of parcels, newly created lots, streets, easements, slope, natural features, storm-water facilities, open areas and structures for preliminary reviews, the preservation of land records, and property tax assessments.

Kent County’s Development Advisory Committee (DAC) currently reviews major subdivisions, site plans, and conditional uses with site plans. A major subdivision is defined as the creation of more than five lots, and/or where the creation of two or more lots results in the creation of a state-maintained road. (A minor subdivision is defined as the creation of four lots or less plus the residual, not involving the creation of a public or state-maintained road. Further subdivision of the residual lot may be done under minor subdivision regulations provided that the lots are 20 acres or more in size.) Site plan review is required for all multi-family dwellings containing 10 or more units or comprising two or more buildings, town houses, manufactured home parks, hotels, motels, and business, commercial, industrial, or buildings with over 5,000 square feet of floor area. Certain conditional uses also require site plan review; they are specified in the county’s zoning ordinance.

**Sussex County**

Sussex County has separate Zoning and Subdivision Ordinances that govern zoning and the subdivision of lands. All subdivisions, where new road construction will occur, are sent through the Sussex County Technical Advisory Committee for review and comment by the Department and other agencies. Single lots that are created and do not require a street or road to be built are required to have all necessary permits before a building permit is issued.

### 2.8.3.2 Septic Issues

Current state septic regulations governing the design, installation, and operation of on-site wastewater treatment and disposal systems deny the placement of standard (gravity and elevated sand mounds) and/or alternatively designed low-pressure pipe septic systems on soils where the seasonal high water table is within 20 inches of the soil surface. As an option for those property owners, the septic regulations allow for alternatively designed septic systems on a case-by-case basis. These alternative septic systems utilize technologies that pre-treat the effluent to a specific level, usually to levels below 10 ppm of nitrate-nitrogen. Total and fecal coliform levels are also significantly reduced within these pretreatment units. The soil must still dispose of the effluent generated. The cost of these pretreatment units has dropped significantly (from $12,000 – $15,000, to $10,000 – $12,000) so that more people can afford them.

A problem arises on many of the parcels where alternative technologies would be utilized. These parcels are inherently wet, and many are freshwater wetlands. When the water table is within 10 inches of the soil surface, it is difficult to get an elevated sand mound to work properly. Thus, on parcels where the seasonal high water table is expected to be within 10 inches of the soil surface, the Soil Assessment Branch has required that observation wells be installed to verify the depth to the seasonal high water table. If the water table is within 10 inches of the soil surface during the monitoring period, the parcel is considered unacceptable as a site for an alternative septic system. However, the Department has granted variances in certain instances where site-specific conditions may minimize ground-water mounding. Most of these sites are located in wooded areas with hydrophytic vegetation indicative of wetlands. Most soils are hydric and in many cases the wetland hydrology has been observed. These sites are jurisdictional wetlands as defined by the Clean Water Act and as delineated with the 1987 Army Corps of Engineers Wetlands Delineation Manual.

In the past, on parcels considered to be freshwater wetlands, the Department informed the property owner of the possibility that their parcel may contain jurisdictional wetlands, and depending on the location of the wetland (i.e., isolated, adjacent or headwater), a permit from the appropriate federal agency might be needed. In most cases, the appropriate federal agency was not notified.
Consequently, freshwater wetlands are slowly being replaced with residential development one acre at a time.

2.8.4 LAND-USE CONCERNS

2.8.4.1 Strip Development

Strip development is a development pattern that occurs in rural areas along roads. Typically, this development is a form of sprawl in which land is converted from natural or agricultural uses to small-lot residential homes. Usually these homes line a road on one-acre lots with one driveway per home. Both water and wastewater are the responsibility of the homeowner who has little option but to use an on-site septic tank for wastewater disposal and a shallow well for water supply. This type of development is common in the Chesapeake Basin. It seems to occur close to a municipality and is prevalent in the growth areas of Sussex County. This pattern is evident by the distribution of domestic septic systems shown on Map 2.8-1 Strip Development and Growth Patterns.

Strip development is generally considered a poor form of development as it causes a loss in highway capacity with its one driveway per home ratio; takes productive farmland out of production; puts demands on public services (school buses, state police, etc.); contributes to ground-water pollution from the septic tank; and increases air pollution due to longer car trips to commercial areas to acquire needed goods and services.

2.8.4.2 Sunsetting

Sunsetting is the termination of an approval to develop a tract of land to another use when there is a lack of any meaningful progress towards the proposed use. Frequently, a five-year benchmark is employed to ascertain if progress is being made.

In New Castle, zoning was sunset with the adoption of the UDC. There is some relationship between the older zoning and new UDC zoning standards. In the U.S. 301 area some Commercial zones were reduced down to the current Commercial Regional zone. As of January 1, 1998, new development activity will be sunset if there is no substantial progress toward implementation of plans after five years.

Kent County’s Subdivision and Zoning Ordinances contain sunsetting provisions. In the Zoning Ordinance, if a property is rezoned contrary to the Comprehensive Plan, the property owner has 18 months to commence construction. In the Subdivision Ordinance, if commencement of construction has not begun within five years of final approval by the Levy Court, the recorded subdivision plan shall be expunged.

Sunsetting can be voluntary or mandatory. In the Sussex County portion of the Basin, sunsetting can occur voluntarily by application for landowners possessing commercial land that is agricultural or residential unless the landowner desires to pay the higher property tax based on the unused commercial zoning. There is no cost to the landowner, and many people have received no opposition and unanimous Sussex County Council approval. As of the December 1997 adoption of the Sussex County Comprehensive Plan, all new subdivisions have five years to show substantial progress toward completion or their application will be sunset and the land will return to its original zoning classification. Other subdivisions that were approved prior to the adoption of the 1997 Sussex County Comprehensive Plan will also be sunset unless there is substantial progress toward completion.

The automatic sunsetting of proposed yet unbuilt projects is environmentally favorable. As a minor discouragement to poorly planned growth, less growth in deeply rural areas means less ground-water withdrawals and no septic wastewater released to the water table. The Cabinet Committee on State Planning Issues called for a state goal of “protecting critical natural areas from ill-advised development.”

2.8.5 COUNTY PLANNING

2.8.5.1 Zoning Status

The Quality of Life Legislation was amended under Shaping Delaware’s Future Legislation of 1995. Additional requirements were placed on comprehensive plans in which state agencies were required to provide natural resource and other data to counties. The comprehensive plans and State Capital Budgeting have to consider 11 Shaping Delaware’s Future Goals. Furthermore, the Cabinet Committee on State Planning Issues’ recommendations are also considered.

In New Castle County, the remaining open land has been rezoned at the end of 1997 as part of the UDC. This is intended to put a stop to building that does not resemble the project plans. Other changes include new design standards, as well as tougher environmental standards and landscaping requirements. Requirements for adequate community facilities ensure that approval for new construction occurs after schools, roads, water, sewer, and other essential services are in place or are ready to be built. Impact fees impose a fair cost to new development so that new growth pays its own way.

In the Kent County portion of the Basin, most of the land is zoned Agricultural Conservation (Office of Management, Budget and Planning, 1981).

In Sussex County, a new Conservation Zone Ordinance is being drafted to respond to citizens’ concerns that the concept developed in earlier drafts of the plan was too restrictive. However, a Conservation Zone will most likely include all lands within a specific distance to tidal wet-
lands along the Nanticoke River. The Sussex County Zoning Maps will also designate a smaller growth area bounded by Laurel, Seaford, and Blades, in addition to designated growth areas around towns described in other portions of this section. Recently, Sussex County adopted a measure to reduce the amount of land that is required to get an approval for a mobile home to reduce unauthorized junkyards and other nuisances.

Discussion

Today, zoning controls have generally been upheld with respect to the following areas of collective protection of private property in neighborhoods:

1. Maintaining property values.
2. Stabilizing neighborhoods and preserving their character.
3. Providing for uniform regulations throughout each district. Because planned unit developments often do not conform to this purpose they are sometimes opposed.
4. Providing for moving traffic rapidly and safely. This purpose is frequently used to argue against higher density.
5. Controlling aesthetics. The courts have upheld a denial of permits for structures at variance with existing structures that would cause a depression of property values.

In some areas, rigid zoning controls have given way to “flexible” controls on development. One of the most common is the “wait-and-see” zone.

In the wait-and-see areas, undeveloped lands might be zoned only for exclusive agriculture or large-lot residential uses. However, the city or county is often only waiting for a developer who will propose a zone change that allows the exercise of the widest administrative discretion. These wait-and-see zones may extend to most of the buildable land in a jurisdiction, even though the comprehensive plan and the official zoning map may show something else (Solnit, 1988).

Site plan review is another flexible land-use control. It can be used on its own or as part of the planned unit development procedure. The general idea is that the community receives some assurance that the developer will follow the detailed design plans presented. During these reviews the planning agency has much more to do than simply determine whether or not a proposed development is in compliance with applicable ordinances and codes. The planners must have skills required to negotiate not only on behalf of the jurisdiction and the developer, but also with several other interest groups, including the general public, the residents, and the property owners near the proposed development. They must also negotiate with other landowners and speculators who will be affected by the approval of the proposal under review. One of the most difficult tasks the planning agency has to do is to write conditions of approval that will both be fair and will also stick.

Rural zoning for controlling outdoor advertising or promoting agricultural development, forestry, and recreation is not apparent in this Basin.

Distinctions Between Planning and Zoning

Zoning, as it is practiced, is only part of the process called “planning.” Zoning separates a jurisdiction into districts, regulates land use inside each district, and maintains separation between conflicting uses. However, planning has a much broader focus: it concentrates on development in relation to the community’s current and future social and economic well-being. A practical analogy is that planning measures such as adopted plans, goals, and so forth are official policy for the future, while zoning authorizes and permits uses for specific properties right now.

Every county and town in the state now requires that zoning conform to a “well considered plan” or a “comprehensive plan.” This consideration shows local governments that zoning cannot be truly effective unless the long term is evaluated, and that the comprehensive plan is the means by which the rational allocation of land can be achieved. It should be a prerequisite for zoning.

2.8.5.2 Data Systems

New Castle County uses the GIS that was used by the Water Resources Agency of New Castle County (WRA). The system can use data from the Department’s GIS and has been used to map Water Resource Protection District Overlays and Critical Natural Areas, etc.

Kent County Department of Planning has an implementation plan for Coastal Ocean Management, Planning, and Assessment (COMPAS) Delaware, Resources Protection Module. This is a joint project between Kent County, the Department’s Delaware Coastal Management Program (DCMP), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Fish and Wildlife Service, and the Delaware Estuary Program. COMPAS is a computerized tool developed to assist Kent County in their land-use planning process. The computerized Resource Protection Module may be used in the Site Review/Pre-Application and Growth Management areas of county planning and zoning administration (DCMP, 1997).

Sussex County has a computerized GIS, which has digitized most of the tax-map parcel data for the county. No other use is planned for the system other than managing data for the Assessment Division of Sussex County, which handles property tax administration. It is not known what capabilities the system has for providing county officials with environmental information.

2.8.6 OPEN SPACE AND RECREATION

2.8.6.1 Parks

Recreation is typically defined as any type of conscious enjoyment that occurs during leisure time. Recreation
provides a variety of benefits to the public, including personal, social, economic, and environmental benefits. For example, a walk in the park during a lunch break gives employees a chance to recharge their spirits before returning to work. Athletic activities provide positive alternatives to youth who may otherwise become involved in destructive behavior. Undeveloped parkland along a stream corridor can provide wildlife habitat and filter nutrients before they reach our waters.

Recreational resources are natural or man-made resources that are used to obtain enjoyment during leisure time. These include ball fields, hiking and walking trails, fishing ponds, tennis courts, picnic areas, and other amenities. Parks and greenways provide recreational resources for community use and are important resources to consider as a part of land development processes.

The Chesapeake Basin has more than 20 municipal parks, comprising nearly 60 acres, to serve the active recreation needs of its residents. Active recreation facilities include ball fields, swimming pools, and playgrounds. All of these municipal parks are located in Sussex County, where the bulk of the Basin’s population resides. One state park, Trap Pond, lies within the Basin’s boundary, also in Sussex County. Kent County manages some open space in the Basin near Felton. The Chesapeake Basin also includes two state-managed wildlife areas and two state forests. State parks, county open space, state wildlife areas, and state forests help to meet the population’s needs for passive recreation, such as fishing areas, hiking and walking trails, and wildlife-watching. Map 2.8-2 Recreation Sites shows the locations of these parks and wildlife areas.

According to a 1995 survey conducted as a part of the Statewide Comprehensive Outdoor Recreation Plan (SCORP) process, recreation needs in the Chesapeake Basin are inadequately met. While the Chesapeake Basin encompasses significant amounts of state-managed wildlife areas, forests, and nature preserves, the amount of local and regional parkland developed for active recreation is lacking. As the population of the Chesapeake Basin grows, and development pressures in the Basin heighten, acquisition and development of parkland and recreation facilities in and around population centers will be important to maintaining a high quality of life for Basin residents.

The Chesapeake Basin includes roughly 60 acres of local open space and parkland, or about 1 acre per 1,000 population. This number falls significantly short of the National Recreation and Park Association (NRPA) recommendation of 10 acres of local parkland per 1,000 population. However, as previously noted, these local parks are concentrated in the Sussex County portion of the Basin. Nearly 27 percent of the Chesapeake Basin residents live in New Castle and Kent counties, where there are no municipal parks. Chesapeake Basin residents in New Castle County are served by parks outside the Basin (in Newark, Middletown, and unincorporated areas in New Castle County). Residents in the Kent County portion of the Basin have few active recreation areas nearby. Additionally, Sussex County’s local parks are concentrated in the Seaford and Laurel areas. Chesapeake Basin residents outside of these municipal areas have inadequate access to local parks.

According to the 1995 SCORP survey, residents throughout the Chesapeake Basin and elsewhere in the state would like to see more hiking and walking trails, bicycle paths, and paved walkways. These amenities can be incorporated into community greenways, or open space corridors, which can link parks with neighborhoods, commercial centers, schools, and historic and cultural sites. The City of Seaford and the Town of Laurel are in the process of developing riverfront walkways as a part of downtown revitalization. Efforts need to be made Basin-wide to expand such initiatives and create pathways that connect our communities and provide recreational opportunities along with alternative transportation routes.

In addition to the need for pathways and trails, residents of the Chesapeake Basin also expressed a need for playgrounds and tot lots; programs for teens, people with disabilities, and the elderly; historic and nature education programs; fishing and boating areas; swimming pools; and ball fields.

To help county and municipal governments better meet the recreation needs of Chesapeake Basin residents and all Delawareans, the Division of Parks and Recreation offers a variety of assistance to local governments. Matching park and greenway grants through the Delaware Land and Water Conservation Trust Fund provide financial assistance to county and municipal governments for park and greenway planning, acquisition, and development. The Division also has a variety of technical assistance available to local communities, including park and open space guidelines and design standards, trail construction and maintenance publications, and other resources that communities can use to develop recreational facilities to meet the needs of their residents.

As development is planned in the Chesapeake Basin, it will be important to ensure that adequate recreation facilities are planned to serve the Basin’s residents.

2.8.6.2 State Resource Areas (SRAs)

In 1990, the Land Protection Act was signed into law, thereby creating Delaware’s Open Space Program. As a part of this program, 20 SRAs were created, including state, federal, local, and private conservation lands and inholdings, and potential additions to these areas. Part of the mission of the Open Space Program is to protect lands within these SRAs through purchase, donation, or conservation easement.
The Chesapeake Basin includes portions of five SRAs: Chesapeake and Delaware Canal, Blackbird, Central Kent, and Ellendale/Redden State Forests, and Great Cypress Swamp, and two entire SRAs: Nanticoke River, and James Branch, and one stand-alone area: Taber State Forest.

The Natural Heritage Program has recently undertaken an analysis of rare and endangered species locations to compare with the state natural area inventory for several of Delaware’s watersheds. More than half of all known occurrences of rare and endangered plants have been outside of natural areas. Such an analysis has not yet been completed for the Chesapeake Basin, but will be in the future. As a result of this analysis, the natural areas inventory will be amended and the Open Space Program will be able to look at expanding its SRAs to better preserve rare ecosystems.

For more information on this subject, refer to the Living Resources Section 2.7.4.

### 2.8.7 CRITICAL AREAS

A critical area is a specific geographic area of the state, or basin, based on studies and resource assessment analysis of physical, social, and economic trends. A critical area is demonstrated to be so unusual, important, or significant to the state or basin that the Department designates it for special management attention to assure the preservation, conservation, or utilization of its special values.

The 1978 Delaware Land Use Planning Act defined a critical area as “an area wherein the establishment or maintenance of a viable physical, economic, or social environment is of more than local concern; or the physical, economic or social characteristics of said area are of primary importance or uniquely sensitive, including, but not limited to wetlands, major port facilities and historic areas.” This bill did not include “...agricultural lands in productive use.”

For purposes of the Whole Basin Management Program, the definition of a critical area can be expanded to include:

a. areas having or containing a significant positive or negative impact upon environmental, natural, scientific, cultural, historical, or archaeological resources.

b. areas significantly affected by, or having a significant effect upon, an existing or proposed major public facility or other areas of major investment which are intended to serve substantial numbers of people beyond the vicinity in which the development is located and which tends to generate substantial development or organization.

The phrase “of more than local concern” is meant to describe those areas where uncontrolled or incompatible large-scale development (or change in present use) could result in damage to the environment, life, or property where the short- or long-term public interest is of more than local benefit. Examples of land uses of more than local benefit include state parks and dedicated business centers.

A critical area has a sense of uniqueness, quality, rarity, and/or economic benefit to the greater community. They are sensitive and vulnerable to uncontrolled growth or development that may be incompatible with them.

The critical areas of the Chesapeake Basin have been categorized as either natural and cultural, economic, or public infrastructure. Suggested critical areas within the Basin are listed in Table 2.8-4 under these three categories.

### Table 2.8-4

**EXAMPLES OF CHESAPEAKE BASIN CRITICAL AREAS**

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>AREAS OF CONCERN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural &amp; Cultural</td>
<td>Nanticoke River Riparian Corridor with wetlands</td>
</tr>
<tr>
<td></td>
<td>Broad Creek Riparian Corridor with wetlands</td>
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<td>Marshyhope Creek Riparian Corridor with wetlands</td>
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<td>Economic</td>
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<td>Agricultural Preservation Districts</td>
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<td>RR bridge over C&amp;D Canal</td>
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<td>STP’s (Delmar, Laurel, Seaford, Greenwood)</td>
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<td>Rte. 13 Right-of-Way</td>
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<td>Schools</td>
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### 2.8.8 COORDINATION WITH MARYLAND (USF&W, NANTICOKE/BLACKWATER GROUP)

Environmental activities in Delaware’s portion of the Chesapeake Basin need to be coordinated with activities in Maryland’s portion of the Basin. The Nanticoke River...
watershed receives more attention from citizens’ groups than other portions of the Basin. This is probably due to the more intense use of this relatively large river by commercial and recreational interests. Listed below are several specific examples of coordination efforts between the two states in regard to the Chesapeake Basin.

1. The Department Planning Office has a liaising effort in place through the Nanticoke Watershed Alliance based in Salisbury, Maryland. This umbrella organization includes the Maryland Department of Natural Resources, U.S. Fish & Wildlife Service, Maryland Office of Planning, the Wicomico Environmental Trust, The Nature Conservancy, the Chesapeake Bay Foundation, as well as several corporate members of the alliance.

2. Cooperation with the U.S. Army Corps of Engineers, which is responsible for navigation issues on the Nanticoke River and the Chesapeake & Delaware Canal. The Corps’ Baltimore Office has jurisdiction over the Nanticoke River.

3. The Department staff have participated in discussions with the U.S. Fish and Wildlife Service, Maryland Department of Natural Resources, and private conservation organizations to develop a land protection strategy for the Nanticoke, south of Seaford.

2.8.9 HISTORICAL AND ARCHAEOLOGICAL RESOURCES

Human occupation of the Delmarva Peninsula began more than 12,000 years ago. Since that time, thousands of archaeological sites and aboveground structures and buildings have been created. These cultural resources reflect the lives of the people who lived and worked here. Although most of the aboveground historic period resources dating before 1945 in Delaware have been recorded, only a small percentage of the prehistoric and historic period archaeological sites have been identified.

Over the last decade, the Delaware State Historic Preservation Office has commissioned three statewide historic preservation management plans covering both aboveground and belowground (archaeological) resources. These management plans address the types of cultural resources likely to be found in each physiographic zone (or management unit) of the state, for specific periods of prehistory and history. Priority guidelines for research and preservation are established, and stresses on resources are discussed.

The prehistoric resource management plan places the Delaware portion of the Chesapeake Basin within the Interior, Nanticoke Mid-Drainage, and Interior Swamp (James Branch and upper Pocomoke) management units. Overall data quality for all three management units is listed as poor, although several studies conducted after the publication of the statewide management plan have improved this situation for the James Branch and Nanticoke. Based on information available at the time the management plan was prepared, all three management units have a low probability for significant examples of most site types for the earliest periods of prehistory (Paleo-Indian and Archaic). The Nanticoke Mid-Drainage and Interior Swamp management units have a high probability for significant sites of all types for the Woodland I and Woodland II periods of prehistory. Contact Period sites are most likely to be found in the vicinity of the Nanticoke River.

Residential development and the expansion of farm fields cause stresses on prehistoric resources. These two processes are often related because farmers sell off strips of land along roads for development and then clear the wooded strip at the back of the farm. The expansion of farm fields is of particular concern because previously wooded strips along streams are being cleared, exposing sites that had previously been protected by the woodlands.

The management plan for historic period archaeological resources does not define specific geographical management units. Data quality for historic archaeological resources is generally poor statewide, but it is possible to make general statements about the frequency and distribution of sites dating to specific time periods. In the Chesapeake Basin, early European settlement (1630 to 1730) was concentrated along the Nanticoke River and the Marshyhope Creek. Population growth in this area was slow until after the Revolution because disputes between the Maryland and Pennsylvania proprietors made it difficult to determine whether grants of land were secure. In general, settlement was most concentrated along transportation routes and in urban centers, most of which still exist today. Rural industrial sites, including sawmills, gristmills, and iron forges, may be preserved along stream valleys. More urban industrial sites, including boat yards as well as factories, are also sometimes preserved.

Stresses on historic period archaeological resources, especially those dating to the first period of settlement, are similar to those identified for prehistoric archaeological resources. Development along roads threatens late 18th- and 19th-century sites oriented along transportation routes. The Marshyhope and Nanticoke watersheds are identified as areas of particular stress on historic period archaeological sites. Urban industrial sites are also threatened by development.

The Delaware Comprehensive Historic Preservation Plan sets priorities for the Identification, Documentation, and Preservation of aboveground historic period resources. Priorities are expressed in terms of broad themes reflecting the social and economic history of the state. The Chesapeake Basin is located primarily in the Upper and Lower Peninsula geographic zones as defined in this plan. Priority themes for these zones include Agriculture and Settlement Patterns, and Demographic Change.
Aboveground resources are threatened both by development and by deterioration. Development often results in the demolition of otherwise intact and usable buildings or structures, even when a building could be incorporated into the development, as when an historic farmhouse is rehabilitated as one of the residences in a housing development. Even when not threatened by new development, buildings may succumb to age. They are often replaced by new buildings and relegated to use as secondary structures. Eventually, they fall into disrepair and are abandoned.

Perhaps the greatest threats to cultural resources of all types are actions that do not require federal funds or permits. Under the National Historic Preservation Act of 1966, as amended, effects on cultural resources must be taken into consideration when planning federal actions. Some states have attempted to institute similar programs for non-federal actions, but such programs are expensive to implement and often not popular.

### 2.8.10 BUFFERS AND CONSERVATION ZONES

Other factors remaining equal, fouling of the state’s precious aquatic resources and natural streams occurs with greater frequency unless naturally vegetated buffers are present on their edges and boundaries to control sedimentation, erosion, nutrients, and runoff. Buffers reduce the potential for eutrophication, control water temperature, maintain dissolved oxygen concentration, and provide crucial wildlife habitat. These buffer areas preserve waterways, wetlands, and floodplains that perform crucial, cost-effective drainage and flood control without general public subsidies and direct tax assessments.

Some benefits of forested streamside buffers:

- Maintain and restore the chemical, physical, and biological integrity of water resources.
- Remove nutrients and toxics from runoff and ground water.
- Reduce erosion and control sedimentation.
- Stabilize stream banks.
- Provide infiltration and attenuation of storm-water runoff.
- Maintain stream base-flows during dry periods.
- Provide organic matter that is the source of food and energy for aquatic ecosystems.
- Provide shade to streams and encourage desirable aquatic species.
- Provide riparian habitat for insect-eating birds and other wildlife.
- Provide scenic value and recreational opportunity.

- Minimize public investment in waterway restoration, storm-water management, and other water resource expenditures that eliminate the meandering course on which streams depend for their ecological variety.

Aquatic resources’ ability to treat pollution without public investment is enhanced if the plant and animal community and a portion of its surrounding uplands are left intact. Storm-water facilities should not be placed in wetlands or riparian areas. The construction of the facility damages the aquatic system, while actual operation of the storm-water facility causes sedimentation and eutrophication. Other damage occurs when aquatic systems are excavated to remove accumulated sediments. Aquatic resources are stressed beyond their natural limits, and significant reduction or elimination of their pollution removal ability and other functions occur when the surrounding uplands are disturbed. Forested buffer strips between most uses of land riparian systems can significantly protect the functions and values of aquatic resources.

Different types of vegetation in riparian landscape buffers can affect their capability to remove nonpoint source pollutants; improve stream quality, wildlife habitat and fish habitat; and perform other buffer functions. Grass has low value for improving wildlife, water quality, and aquatic systems; herbaceous buffers made up of wildflowers or legumes have low-to-medium value; shrubs have medium-to-high value; and forests have the greatest value. Forested riparian buffers can be designed for management to maintain nutrient uptake and provide for the harvesting of natural products.

There are two basic approaches for delineating riparian buffers. The first approach is to use a fixed setback between soil disturbance and the aquatic system. The principal advantage to this approach is that it is universal in its application and does not require detailed environmental assessments to provide some benefits to the community. It can be used effectively where impacts to watersheds and land prices are low. However, it does not recognize the importance of slopes, erodible soils, irregular wetland or floodplain boundaries, and stream/wetland classification. The second approach to buffer strips is through the delineation of a floating buffer whose width changes to accommodate these factors not considered in the first approach. It recognizes the presence of land with low environmental sensitivity that may be in proximity to an aquatic system, and is more effective than the fixed buffer arrangement for controlling impacts to watersheds from land-use changes. However, it does require a detailed environmental assessment of site conditions, and a well-developed land-planning administration in order for it to be translated into benefits for the community (Mantell et al., 1990).
2.8.11 DATA GAPS AND RECOMMENDATIONS

1. The Department should encourage the three counties to have a (two or three year) sunset time of rezoned land in the non-urban growth areas of this Basin. Land in urban growth areas should have a longer time span for initiating new construction on rezoned land.

2. For large single-use projects, in areas where development is not encouraged, there is an opportunity to use the LUPA process more effectively to discourage sprawl. The Department should more actively seek agreement with the Office of State Planning on the definition of what is “more than local concern” and therefore trigger reviews under LUPA to protect open space.

3. The Department should support the new county sewer district in the greater Summit area north of Middletown to reduce the potential for contamination of the water-table aquifer.

4. Corridor preservation for reducing air pollution and runoff and reducing sewer construction should be supported by the Department along U.S. 301 and other major corridors.

5. Comprehensive plans that are relevant today may become obsolete tomorrow. Most planning and zoning relationships must be reassessed on a continuing basis to guarantee that important land functions continue to operate while the land is used, no matter what the use.

6. The Department should encourage the development of recreation facilities in and around population centers; encourage the inclusion of usable open space in the subdivision process; and work with local communities throughout the Basin to help them meet the recreation needs of their residents.

7. Development of lands within State Resource Areas, Natural Heritage Sites, Natural Areas Inventory, and Old Growth Forests should be discouraged.

8. Critical Areas should be accorded special status and given special attention when a development is proposed on or adjacent to such an area. It is recommended that state and local governments care for these areas. Their actions and decisions should reflect a major commitment toward protecting and conserving these resources.

9. Implement requirements for buffer zones along streams to protect prehistoric and early historic period archaeological sites.

10. Establish historic review boards, such as the one in New Castle County, which will result in proactive measures to preserve historic buildings and efforts to record important features of those that cannot be preserved.

11. Preservation and restoration of riparian buffer for both natural streams and tax ditches should include new, environmentally friendly, techniques for tax ditch maintenance, inter-agency coordination, and public/governmental education.

12. Develop model zoning ordinance favoring riparian protection.

13. Recommend, whenever practical, the use of non-structural alternatives for erosion control. A combination of rip-rap with natural vegetation should be emphasized where shoreline erosion is a problem for property owners.

14. Work with county and municipal governments to develop and update open space ordinances.

15. Promote forested riparian buffers in Environmentally Sensitive Areas.

16. Towns are finding that their zoning codes, conceived and written in the 1960s, do more to prevent rather than manage economic growth. Traditional tools such as Neighborhood Districts, Village Overlays, Transit Oriented Overlays, and updating town comprehensive plans, should be supported to direct growth in areas where infrastructure already exists.

17. Intergovernmental coordination zones should be designated in growth areas and areas likely to be annexed to provide the latest and best data to decision-makers.

18. A study should be undertaken to determine the maximum density an urban growth area must attain before additional undeveloped land is added to the urban growth area. After a density determination is developed, the State Cabinet Committee on State Planning Issues may establish policy regarding infrastructure expansion when density of an urban area is below the threshold value.

19. Encourage update of town plans. The Department, in conjunction with the Office of State Planning Coordination and the Sussex County Planning Department, should encourage the towns of Greenwood, Bridgeville, Seaford, Blades, Laurel, and Delmar to develop comprehensive plans. The plans would, among other things, prioritize the areas in and around the towns for sewer and water service and annexation procedures. The plans should include a transportation element, conservation element, and economic development element.

2.8.12 REFERENCES


Delaware Department of Natural Resources and Environmental Control. 1995. Regulations Governing the Design, Installation and Operation of On-Site Wastewater Treatment and Disposal Systems. Dover, DE.


This chapter is a condensed summary of the major issues and recommendations that are detailed in Chapter 2. They have been organized into three main categories: Nutrient Management, Sensitive Resources, and Non-Nutrient Contaminants. Within these main categories, specific issues have been grouped into high, medium, and low-priority concerns. For each of these concerns there is a brief discussion of the issue followed by the Chesapeake team’s related recommendations. The recommendations have been slotted into two groups: Type I – Those over which the Department has direct control, and Type II – Those beyond the Department’s jurisdiction. This chapter’s structure allows the reader to identify the Chesapeake Basin’s most pressing issues, understand them better, and see what can be done to start addressing them.

3.1 NUTRIENT MANAGEMENT ISSUES

According to the 1998 (305(b)) Watershed Assessment Report, nutrients pose a serious threat to water quality, aquatic life, and human health. The enrichment of lakes, ponds, bays, and estuaries by nitrogen and phosphorus from surface runoff and ground-water discharge is known to be a contributing factor to eutrophication. Agricultural runoff, urban runoff, and municipal and industrial point source discharges are the primary sources of nutrients. In many watersheds of the Chesapeake Basin, agriculture is the major land use. Poultry production is a major industry in Delaware. Intense animal livestock production tends to create an imbalance of nutrient input to export resulting in an accumulation of nutrients that lead to leaching, erosion, and runoff of excess nutrients to ground and surface waters.

Nitrogen can be transported from organic waste-amended soils into ground waters by leaching and to surface waters by erosion or runoff. Nitrate leaching is a major concern in humid regions with excessively well-drained soils that overlay shallow water tables. These conditions are common throughout Delaware. If nitrate enters ground-water supplies, two major environmental problems can occur. The consumption by humans or animals of drinking water with high nitrate levels has been associated with several health problems, the most serious being methemoglobinemia (O₂ deficiency in blood) in infants. Additionally, ground waters with high nitrate levels that discharge into sensitive surface waters can contribute to the long-term eutrophication of these water bodies. Erosion and surface runoff can transport soluble inorganic nitrogen and organic nitrogen to surface water. Most of the nitrogen lost in this manner is sediment-bound organic nitrogen. Although the solubility of nitrate favors its loss in runoff as opposed to sediment transport, total nitrogen losses from most watershed studies are usually several fold greater than soluble nitrogen.

In the Chesapeake Basin, phosphorus is the major nutrient that is most frequently found to limit plant growth in freshwater streams. Phosphorus contributes to eutrophication by its movement into surface waters through erosion, runoff, and subsurface flow in artificial drainage and ground-water discharge. Accumulation of soil phosphorus to excessive levels must be minimized to reduce the transport of soluble or sediment-bound phosphorus to sensitive water bodies. Because crop production systems are forced to continually use manure as fertilizer, due to the lack of...
economically viable alternatives for manure disposal, the systems almost always build soil phosphorus levels well beyond the ranges considered optimum for most agronomic crops. The unfavorable N:P ratio in most manures also results in over-application of manure phosphorus relative to crop needs; to meet crop needs for nitrogen, phosphorus must be over-applied.

3.1.1 TOTAL MAXIMUM DAILY LOADS AND POLLUTION CONTROL STRATEGIES

A Total Maximum Daily Load (TMDL) sets a limit on the amount of a pollutant that can be discharged into a water body and still protect water quality. The Nanticoke River and Broad Creek have been identified as streams with water-quality concerns. As such, they were targeted for TMDL development by December 15, 1998. The major environmental problems in these waters are nutrient over-enrichment and low dissolved oxygen levels. These problems are caused by both point and nonpoint sources.

By Secretary’s Order No. 98-W-0045, the Department has adopted the TMDL Regulations for nitrogen and for phosphorus for the Nanticoke River and Broad Creek. The effective date of the final regulations was December 10, 1998. These regulations require a 30 percent reduction in the loading of both nitrogen and phosphorus to these water bodies.

The next step is the development and implementation of Pollution Control Strategies to achieve these TMDLs. Pollution Control Strategies for nutrient management can vary from point discharge elimination to Best Management Practices (BMPs) for agriculture. The remainder of this section details the Chesapeake Basin Team’s recommendations that could be used as part of the overall Pollution Control Strategies from the Nanticoke River, the Broad Creek, and the rest of the Basin.

3.1.1.1 Riparian Areas

The land immediately adjacent to streams, rivers, or other water bodies is referred to as the riparian corridor. These riparian areas are very important for enhancing both ecological and water-quality values because they maintain unbroken wildlife corridors to the floodplain area, and reduce sediment and nutrient loading downstream. Riparian areas can act as effective nutrient and sediment buffers for their streams by improving the quality of water moving through these areas. Most of the water entering the streams in the Basin initially passes through these riparian buffers. Therefore, protecting these riparian areas can aid in safeguarding the ecological integrity of the larger downstream floodplain systems.

Recommendations — Riparian Areas

High Priority — Riparian Areas:

Type I

- Develop Best Management Practices and an accompanying manual that promotes riparian buffers to help trap nutrients and improve water quality in both channelized and natural streams. (2.6.11 #9, 2.3.5.1; #5)

Type II

- Promote the establishment of forested wetlands and upland forest to supplement and/or restore natural riparian buffers. (2.6.11 #10, 2.8.11 #15, 2.8.11 #11, 2.7.7 #5, 2.3.5.1; #5)

3.1.1.2 Channelization

Approximately 2,000 miles of tax ditches have been reconstructed in Delaware since 1951. In general, many of these drainage-ditch systems involved channelizing the headwaters of existing natural streams, then constructing ditches out and back from headwater channelization. In past decades, natural streams and wetlands were a lower priority than arable land for farming and development. In addition, water-quality impacts and possible habitat losses associated with the “way” drainage ditches were constructed or maintained were not really considered. Drainage systems were constructed as efficiently as possible.

Drainage construction and maintenance efforts do impact water quality and wildlife habitat. Research indicates that drainage systems play an important role in the release and transport of nutrients and bacteria. They also disrupt habitat. In many areas, natural riparian vegetation is removed, affecting upland and transitional habitat for many animal and bird species. Lack of canopy affects in-stream temperature and dissolved oxygen parameters, which in turn disrupts biological integrity and diversity.

In light of accumulated information, the state’s drainage program has developed and is implementing a number of management practices to address these concerns. A need has been expressed to review these existing practices, define a process that allows consistent use, and track implementation.

The Conservation Reserve Enhancement Program (CREP) is providing increased incentives for landowners to implement certain Best Management Practices (BMPs) to improve water quality and enhance wildlife habitat. CREP is focusing efforts on implementing riparian buffers and grass filter strips, increase wildlife habitat acres, and restore wetlands in targeted water quality and wildlife habitat degraded areas. It is expected that implementation of this program will advance Delaware’s goal of meeting water-quality standards.
Implement the channelization BMP manual that promotes riparian buffers to help trap nutrients and excessive land runoff. Alternative maintenance techniques should be considered, including saving trees, mowing along one side of ditch, use of herbicides for those landowners who refuse to establish woody vegetation, or not mowing at all. (2.6.11 #11, 2.3.5.1; #6 & 7)

Promote ways (utilizing brochures) for landowners affected by ditching to easily obtain monies from Conservation Districts for ditch improvement projects and riparian buffers. (2.7.7 #17)

Educate the agricultural community and other people affected by ditching that drainage and wetlands habitat can coexist if managed properly. (2.6.11 #12)

Require the use of existing and new BMPs for channel construction activities. (2.6.11 #13, 2.7.7 #5)

Finalize products of the Department’s Comprehensive Tax Ditch Committee. (2.6.11 #14)

### 3.1.1.3 Pond Management

Many of the ponds and lakes within the Chesapeake Basin can be classified as eutrophic due to heavy infestations of algae and aquatic weeds. Although the natural aging process tends to fill a pond in over time, the rate has been greatly accelerated by land-use practices adjacent to and upstream from the ponds. Development, farmland runoff, storm events, and heavy use of fertilizers have served to increase the nutrient and silt loads to high levels. This has resulted in excess growth of aquatic weeds and algae, which can impede water-based recreation, adversely affect fish populations, degrade adjacent streams, and cause displeasing odors.

The present “solution” of weed harvesting and herbicide application is similar to mowing the lawn. While they serve as a temporary solution, the nutrients are still available in the substrate and the water column in excess levels. Concurrently, nutrient inputs continue to be high. A long-term solution relies in responsible management of the lands surrounding and affecting these water bodies. Private and public landowners who reside on or manage these lands need to alter land-use practices to reduce nutrient inputs.

### Recommendations — Pond Management

**High Priority — Pond Management:**

**Type I**

- Recommend that the Department develop BMPs for pond maintenance and remediation. (2.6.11; #2)

- Examine current pond management approaches and develop a more effective, broad-based management approach. Educate pond managers and concerned public to the problems confronting the eutrophication problem in ponds. (2.6.11 #5, 2.7.7 #8)

### 3.1.1.4 Department Policy and Future Direction

A reduction in the amount of nitrogen and phosphorus reaching the water bodies of the Chesapeake Basin is necessary to reverse the undesirable effects. These nutrients enter the water bodies from several sources including point sources, nonpoint sources, and from the atmosphere. Point sources of nutrients are end-of-pipe discharges coming from municipal and industrial wastewater treatment plants and other industrial uses. Nonpoint sources of nutrients include runoff from agricultural and urban areas, seepage from septic drainfields, and ground-water discharges. Atmospheric deposition comes from both local and regional sources, such as motor vehicle exhaust and emissions from power plants burning fossil fuel.

On December 10, 1998, the Department adopted nutrient Total Maximum Daily Loads (TMDLs) for the Nanticoke River and Broad Creek. These regulations call for 30 percent reduction in nitrogen and phosphorus loads from point and nonpoint sources.

The attainment of TMDLs for the Nanticoke River and Broad Creek watersheds within the state will be achieved through development and implementation of Watershed Restoration Action Strategies (WRASs), which will consist of many Pollution Control Strategies (PCSs). The WRASs will be developed by the Department in concert with the Department’s ongoing Whole Basin Management Program, Tributary Advisory Teams, and the affected public.

The purpose of WRAS is to initiate actions that will reduce the nutrient loads to impaired water bodies that do not meet Delaware’s water-quality standards. The proposed WRAS will be accomplished by optimizing Best Management Practices (BMPs) for nutrient removal at existing to point sources facilities and by developing and implementing pollution control strategies for nonpoint sources. To effectively implement the WRAS, there must be extensive effort to educate the citizens of Delaware about the process and impacts of that process on their living, working, and playing. Consequently, a myriad of opportunities exists to educate both the public and private sector on the effects of the PCSs on their daily lives.

TMDLs required for the Chesapeake Basin are as follows:

- **Nanticoke River and Broad Creek Main Stems 1998**
- **Nanticoke River and Broad Creek Ponds and Tributaries 2000**
- **Choptank, Chester, Marshyhope, and Pocomoke Listed waters 2005**
**Recommendations — Policy**

**High Priority — Policy:**

**Type I**

- Continue to promote and financially support conservation planning in the Chesapeake Basin and use COMPAS GIS technology to document implementation of Best Management Practices (2.3.5.1; #1)
- Recommend use of septic mapping data in the development of Pollution Control Strategies (2.3.5.1; #14)
- Provide cost-sharing on poultry litter movement from areas of high concentration to areas where it can be utilized to meet crop needs as demonstrated in a comprehensive nutrient management plan. (2.3.5.1; #2)
- Offer low-interest loans to poultry companies to retrofit feed mills for nutrient reduction in poultry litter. (2.3.5.1; #12h)
- Advocate cover-crop program. (2.3.5.1; #4)
- State that P/N nutrient management system is needed. (2.3.5.1 #9)
- Finalize and Adopt updated P Index. (2.3.5.1 #8 & #10)
- Recommend that state develop Animal Feeding Operations strategy (permits, BMPs, etc.). (2.3.5.1 #15)
- Focus nutrient management plans for intensive animal-based agriculture on farm-scale nutrient balance rather than exclusively on field-scale crop response to nutrients applied in animal wastes. (2.3.5.1 #11)
- Develop economically viable alternative uses of manure; encourage expedited demonstrations into composting, post-composting processing, and market potential of composted products. (2.3.5.1 #12d)
- Support implementation of phytase feed lines by all integrators on the shore by year 2003. (2.3.5.1 #12g)
- Identify the areas where a significant amount of ground water is being consumed and the Department has little or no water-quality data. (2.3.5.1 #16)
- Develop and implement pollution control strategies to meet established TMDLs for Nanticoke and Broad Creek. (2.3.5.1 #17)
- Develop and implement storm-water monitoring plan. (2.3.5.1 #19)
- Begin development of TMDLs for remainder of Basin. (2.3.5.1 #18)
- Eliminate all Combined Sewer Overflows in Basin. (2.3.5.1 #20)
- Synchronize NPDES permits in watersheds/basins. (2.3.5.1 #21)

- Review septic regulations considering TMDL/PCS issues. (2.3.5.1 #22)
- Implement the Conservation Reserve Enhancement Program (CREP) in the Chesapeake Basin on 2,000 to 3,000 acres by the year 2002 for the following Best Management Practices: filter strips, riparian buffers, wildlife habitat restoration, and shallow wildlife areas. (2.3.5.1 #5)
- Develop depth to ground-water maps for the entire state that highlight areas with an extremely shallow water table (2.1.5 #2, 2.5.4 #10)
- Review irrigation well-water quality for nutrient loading. Incorporate in Management Plans. (2.5.4 #11)
- The Department should closely monitor Maryland's *Pfiesteria* Action Plan as it contains proposed land-based solutions to the overall nutrient-loading problem. (2.3.5.1 #12)

**Type II**

- Rather than control economic growth, town zoning codes, which were conceived in the 1960s, prevent it. Traditional Neighborhood Districts, Village Overlays, Transit Oriented Overlays, and updating of town comprehensive plans partially or completely, etc., should direct growth to areas where infrastructure already exists. (2.8.11 #16)
- Intergovernmental coordination zones should be designated in growth areas and areas likely to be annexed to provide the latest and best data to decision-makers. (2.8.11 #17)
- The Department should encourage the three counties to have a (two- or three-year) sunset time of rezoned and subdivided land in the non-urban growth areas of this Basin. Land in urban growth areas should have a longer time span for initiating new construction on rezoned land. (2.8.11 #1)
- Work with counties and local governments to coordinate septic regulations for greater (average) open space for unsewered areas. (2.3.5.1; #23)

**Medium Priority — Policy:**

**Type I**

- Targeted ground-water monitoring should be incorporated more frequently into BMP implementation projects. If possible, monitoring plans should be developed to discern short-term effects and predict long-term trends to provide a better indication of implementation impact. (2.3.5.1; #3)
- Amend the septic regulation to provide for more appropriately located large community septic systems. (2.3.5.1; #24)
- Review analytical site data from all site types for any available nutrient information. (2.3.5.1; #31)
- Recommend that the Department deny the placement of new (non-replacement) alternative septic systems outside of investment areas and restrict their placement in investment areas to reduce impacts to wetlands and important habitats. (2.3.5.1; #25)
- Assess septic system failure rate for the Chesapeake Basin through remote sensing and verification by grounding survey. (2.3.5.1; #26)
- Determine ground-water system lag time in various sites throughout the state. This could be very helpful in establishing timetables to see results of Pollution Control Strategies. (2.5.4; #13)
- Develop a combined strategy to coordinate ground-water sampling and share analytical data. (2.5.4; #1)

**Type II**

- Encourage update of town plans. The Department, in conjunction with the Office of State Planning Coordination and the Sussex County Planning Department, should encourage the towns of Greenwood, Bridgeville, Seaford, Blades, Laurel, and Delmar to develop comprehensive plans. The plans would, among other things, prioritize the areas in and around the towns for sewer and water service, annexation procedures, requiring procedures, etc. The plans should include a transportation element, conservation element, and economic development element. The Office of State Planning Coordination should grant funds for this. (2.8.11; #19)
- Corridor preservation for reducing air pollution and runoff, and reducing sewer construction should be supported by the Department along U.S. 301 and other major corridors. (2.8.11; #4)
- When and where construction is needed, encourage infill to existing developed areas rather than development of "green" spaces. Continue to work with communities to encourage the protection of stream corridors. (2.7.7; #6)

**Low Priority — Policy:**

**Type I**

- Support and develop certification for (required) inspection of septic during property transfer. (2.3.5.1; #27)
- Obtain grants to repair, or replace, malfunctioning septic systems in environmentally sensitive areas. Incorporate innovative technologies where appropriate. (2.3.5.1; #28)
- Continue to research and demonstrate alternative systems, such as gray-water separation, or the placement of sawdust under tile drainage fields. (2.3.5.1; #29)
- Refine regional ground-water flow data with information from all possible sites. (2.5.4; #12)
- Determine more accurate base-flow loading for impacted streams; Compare ground-water and surface-water data for interactions. (2.5.4; #5)
- Analyze up-gradient well data from monitored sites to see if there are any regional trends in ground-water quality. (2.5.4; #4)

**Type II**

- A study should be undertaken to determine the maximum density an urban growth area must attain before additional undeveloped land is added to an urban growth area. This may have serious implications for infrastructure expansion issues. (2.8.11; #18)
- The Department should support a new county sewer district in the greater Summit area north of Middletown to reduce the potential for contamination of the water-table aquifer. (2.8.11; #3)

### 3.1.1.5 Implemented Projects and Pollution Control Strategies

Although action is needed on all of these recommendations in order to better manage nutrients throughout the Basin and the state, the following recommendations were acted upon and are currently in varying stages of implementation. The first two recommendations-turned-projects were conceptualized, planned, and funded as a direct result of the Chesapeake Basin Assessment. The atmospheric deposition study was identified by the Chesapeake Team, but was implemented and funded by the Inland Bays/Atlantic Ocean Team and its associates because it provided a vital piece of information for that basin’s TMDL effort. The wetlands loss project was started outside of the Whole Basin process, but Chesapeake Basin team members provided support.

As the state moves to implement TMDLs and Pollution Control Strategies, it is very important that the lands the government owns or controls be managed properly. Therefore, all agricultural lands owned by state and federal governments must be assessed and have comprehensive conservation plans developed for them. These plans should then be incorporated into the land lease agreements and daily management practices. (2.3.5.1; #30)

With the widespread nutrient inputs throughout the Basin, it is important to locate all of the various sources accurately so that local action can be taken. In particular, as population increases in rural areas, septic systems are installed to dispose of the waste. The regional density of these systems and their proximity to sensitive resources are important pieces of the nutrient management puzzle. Therefore, all septic systems in basins (state) should be mapped using aerial
photography. This information, when placed in GIS format, should be used to answer more specific questions about system placement and density. (2.3.5.1; #13)

Atmospheric deposition is proving to be a major contributor to acidification, nitrogen loading, and toxification of waterways. There is currently little or no specific information on the impact of atmospheric deposition to the Chesapeake and other Delaware basins. It is recommended that options be explored for acquiring the necessary resources to conduct computer modeling and other research to quantify the impact of atmospheric deposition on the Chesapeake and other basins. (2.4.4 #5)

Also, there is a strong need to develop baseline wetland losses in the Chesapeake Basin and identify areas that are losing wetlands due to urbanization and/or agriculture. (2.6.11 #1)
3.2 SENSITIVE RESOURCES

The Chesapeake Basin team has identified a number of very diverse resources in the Basin as being “sensitive.” These sensitive resources can include living resources such as endangered species or fragile habitat, but also include items as diverse as open space, drinking-water supply areas, or even scenic rivers. The Chesapeake Basin contains some of the state’s most picturesque areas. From the Cypress Swamp to the Nanticoke River, much of the natural beauty of this Basin has been preserved. However, habitat loss and degradation due to land-use practices is impacting many of the species that reside in this Basin. Rare and declining species are vulnerable to environmental change and alteration of habitat. Many species exist only in the protected portions of the watershed or rely on certain critical areas for reproduction. This includes both rare and endangered species as well as those considered to be commercially and recreationally important. The locations of some of these critical habitats have not been identified and may be lost before protective measures can be imposed. Therefore, it is not only important to provide protection to known critical areas, but to those areas that have a high potential as well.

3.2.1 RESOURCE PROTECTION

Some of the state’s most valuable natural lands are located in this Basin. Many of these are still intact because most growth has occurred in other areas of the state. In a continuing effort to protect these resources, the Department and other non-profit organizations regularly evaluate these areas and rank them for acquisition or protection. In most cases, these rankings are based on existing data and are grouped with those from throughout the state. The Chesapeake Team feels that, because of its relatively undisturbed nature, much of this Basin should be evaluated more critically to protect pristine areas before they are lost.

3.2.1.1 Surface Water, Ground Water, and Wetlands

Many of the rivers and streams in the Basin are considered to be of exceptional recreational and ecological value. These water bodies have a great impact on the character of this Basin. In fact, much of the recreation and almost all of the Basin’s truly natural areas surround these streams. Not only should these streams be protected, but some effort must be made to protect the ground water that provides much of their water. Ground water is the primary source of drinking water in the Basin and can account for almost 80 percent of the stream flow. Many factors can help improve both surface- and ground-water quality, one of which is the preservation of natural wetlands. These wetlands act as buffers and filters for many of the activities and contaminants that would otherwise enter the ground water/surface water system. In addition, these wetlands provide vital habitat for many of the Basin’s endangered and threatened species. As one can see, this is a complex system that needs to be addressed comprehensively in order to protect many of the Basin’s sensitive resources.

Recommendations — Surface Water, Ground Water, and Wetlands

High Priority — Surface Water, Ground Water, and Wetlands:

Type I

- Promote the acquisition and protection of wetlands and natural heritage sites. (2.6.11 #3)
- Adopt department-wide comprehensive wetland plan. (2.6.11 #4)
- Examine current pond management approaches and develop a more effective, broad-based management approach. Educate pond managers and concerned public to the problems confronting the eutrophication problem in ponds. (2.6.11 #5, 2.7.7 #8)
- Delineation of all source-water protection areas, such as wellhead areas and excellent recharge potential area. (2.5.4 #6)

Type II

- Adopt statewide wetland mitigation policy. Include the concept of “Land Banking.” (2.6.11 #7)
- Prohibit dredging in the Nanticoke upstream of Rte. 13 in Seaford. Siltation and mechanical removal of benthic sediments would disrupt SAV beds, freshwater fish, wetland plants, shoreline vegetation, and benthic invertebrates. (2.7.7 #14)
- Establish wellhead protection ordinances, Best Management Practices, and/or regulations. (2.5.4 #7)

Medium Priority — Surface Water, Ground Water, and Wetlands:

Type I

- Better characterization of metals, pesticides and PCBs in Nanticoke watershed. (2.3.5.2 #2,#5,#10,#15)
- Identify intensive ground water extractive use in areas that may have water availability issues. (2.5.4 #8)
- The location of all facilities with water allocations should be updated and a coverage created in the Department GIS similar to that created for public supply wells. (2.5.4 #2,#3)
Low Priority — Surface Water, Ground Water, and Wetlands:
Type I
✦ Accurately define all sub-cropping aquifer areas to help protect the deeper portions of these aquifers. (2.5.4 #9)
✦ Better mapping accuracy for surface-water intakes including all irrigational uses. (2.5.4 #2, #3, #14)

3.2.1.2 Riparian
Riparian vegetation not only harbors rare species, but also acts as a buffer for adjacent aquatic habitat. Plant roots stabilize banks and impede or filter nutrient-laden runoff from entering directly into the surface water. When this habitat is destroyed or altered, there is a loss of plant and animal species and degradation of water quality. The excess siltation resulting from improper bank management can smother fish egg masses, freshwater mussels, and aquatic vegetation. For some species, this habitat is critical to their continued survival.

Current and existing land developments are often constructed without considering the protection of riparian habitat in the planning process. Many shore residents have installed bulkheads or other hard structures to retard bank erosion, a problem that could have been prevented if riparian buffers hadn’t been destroyed. As riparian habitats continue to be destroyed and degraded, responsible management is lacking and protection of this habitat type is inadequate.

Recommendations — Riparian
High Priority — Riparian:
Type I
✦ Preservation and restoration of riparian buffers for both natural streams and tax ditches should include new, environmentally friendly techniques for tax ditch maintenance, inter-agency coordination, and public/governmental education. (2.8.11 #11)
✦ Develop model zoning ordinance favoring riparian protection. (2.8.11 #12)
✦ Promote activities that eliminate unnaturally high sedimentation and erosion rates, and unnaturally high nutrient inputs. Assess effect of direct stream irrigation on aquatic and riparian systems. (2.7.7 #5)
✦ Recommend, whenever practical, the use of non-structural alternatives for erosion control, or a combination of rip-rap with natural vegetation should be emphasized where shoreline erosion is a problem for property owners. (2.8.11 #13)

Type II
✦ Work with county and municipal governments to adopt zoning ordinance favoring riparian protection. (2.8.11 #12)

Medium Priority — Riparian:
Type I
✦ Encourage stream and pond management that incorporates wide buffers of natural vegetation, including stands of woody species when possible. (2.7.7 #7)

3.2.1.3 Living Resources
An undeniable fact within the Chesapeake Basin is that the species composition of the remaining natural areas has permanently changed. The 18th-century direct habitat conversion of natural areas to agricultural use has altered a functioning natural landscape into a sprinkling of isolated islands and ribbons of natural areas in a sea of agricultural fields. Add to this the introduction of alien species, pollution, excessive sedimentation, altering of natural waterways, etc., and each natural area is further eroded. Therefore, it is imperative that efforts are made to protect the sensitive resources that still exist within this Basin and also throughout the state.

Recommendations — Living Resources
High Priority — Living Resources:
Type I
✦ The Statewide Wetland Mapping Project data should be compared with the Natural Heritage Inventory to identify areas where additional research and/or protection are needed. (2.6.11 #8)
✦ Institute mandatory reporting requirements for commercial American eel harvests to determine the status of the fishery. (2.7.7 #11)
✦ Implement American shad restoration and protection projects including the construction of fish passage facilities (e.g. Records and Concord Ponds), development of a hatchery program, and limiting existing harvests. (2.7.7 #12)

Type II
✦ Identify restoration possibilities to increase connectivity between available habitats (include cooperative opportunities with Maryland). (2.7.7 #19)

Medium Priority — Living Resources:
Type I
✦ Discourage planting invasive exotic plants in Delaware. Encourage the use of native and non-aggressive exotic plant species. Train management personnel to recognize invasives and to develop management strategies. (2.7.7 #9)
✦ Maintain or establish “no wake” zones where needed. The use of non-structural alternatives for erosion control or a combination of rip-rap with natural vegetation should be emphasized where shoreline erosion is a problem for property owners. (2.7.7 #13)
Develop a plan to prevent zebra mussels from becoming established in Delaware (educating anglers, boaters, etc.) (2.7.7 #16)

Type II

Discourage planting invasive exotic plants in Delaware. Encourage the use of native and non-aggressive exotic plant species. Train management personnel to recognize invasives and to develop management strategies. (2.7.7 #9)

3.2.1.4 Department Policy and Future Direction

Protecting the sensitive resources in the Chesapeake Basin requires a coordinated effort between numerous parties. In some instances, this coordination occurs smoothly, while in other instances there are many obstacles. The Department needs to evaluate many of its policies with regard to protecting these resources and initiate the appropriate actions within and outside the agency.

Recommendations — Policy

High Priority — Policy:

Type I

♦ Establish a methodology for discouraging development in Sensitive Areas. (2.6.11 #6)

Type II

♦ The Department should more actively seek agreement with the Office of State Planning on the definition of what is “more than local concern” and therefore trigger reviews under LUPA to protect open space. (2.8.11 #2)

♦ Development of lands within State Resource Areas, Natural Heritage Sites, Natural Areas Inventory, and Old Growth Forests should be discouraged. (2.8.11 #7)

♦ Critical Areas should be accorded special status and given special attention when a development is proposed on or adjacent to such an area. It is recommended that state and local governments care for these areas. Their actions and decisions should reflect a major commitment toward protecting and conserving these resources. (2.8.11 #8)

♦ Implement requirements for buffer zones along streams to protect prehistoric and early historic period archaeological sites. (2.8.11 #9)

♦ Establish historic review boards, such as the one in New Castle County, which will result in proactive measures to preserve historic buildings, and undertake efforts to record important features of those that cannot be preserved. (2.8.11 #10)

Medium Priority — Policy:

Type I

♦ Develop model open space ordinances. (2.8.11 #14)

Type II

♦ Comprehensive plans that are relevant today may become obsolete tomorrow. Most planning and zoning relationships must be reassessed on a continuing basis to guarantee that important land functions continue to operate while the land is used, no matter what the use. (2.8.11 #5)

♦ The Department should encourage the development of recreation facilities in and around population centers; encourage the inclusion of usable open space in the subdivision process; and work with local communities throughout the Basin to help them meet the recreation needs of their residents. (2.8.11 #6)

♦ Intergovernmental coordination zones should be designated in growth areas and areas likely to be annexed to provide the latest and best data to decision-makers. (2.8.11 #17)

♦ Work with county and municipal governments to adopt open space ordinances. (2.8.11 #14)

♦ A dedicated effort to improve and enforce County Comprehensive plans must be made in the future to prevent further degradation of natural resources in the state. (2.7.7 #3)

♦ When and where construction is needed, encourage infill to existing developed areas rather than development of “green” spaces. Continue to work with communities to encourage the protection of stream corridors. (2.7.7 #6)

3.2.2 RESOURCE CHARACTERIZATION

Although there are some highly developed areas in the Chesapeake Basin, much of this Basin is still relatively “natural.” This rural and undeveloped landscape often leads to a scarcity of data about the natural areas that currently exist. As population increases and development pressures expand into the Basin, many of these sensitive resources may become threatened. Therefore, it is vital to adequately characterize these resources prior to this development pressure so that well-informed decisions can be made to implement appropriate and comprehensive protection strategies.

3.2.2.1 Surface Water, Ground Water, and Wetlands

The Chesapeake Basin team defines the sensitive resources in this Basin as including not only the traditional endangered species, but also certain natural features and properties. For instance, ground water, which is the Basin’s primary source of water for both drinking and irrigation purposes, is deemed sensitive because of the potential for severe degradation from many human activities. Additionally, many rivers, streams, and wetlands, which serve as
crucial environmental buffers and habitats, are also appreciated for their aesthetic value and are therefore categorized as sensitive resources.

**Recommendations — Surface Water, Ground Water, and Wetlands**

**High Priority — Surface Water, Ground Water, and Wetlands:**

**Type I**
- Complete recharge-potential mapping for the rest of the state. This mapping shows areas where water and/or contaminants can rapidly enter the ground water. (2.1.5 #1)
- Develop depth to ground-water maps for the entire state that highlight areas with an extremely shallow water table. (2.1.5 #2)
- Support additional funding for statewide soil survey mapping update. (2.1.5 #3)

**Medium Priority — Surface Water, Ground Water, and Wetlands:**

**Type I**
- Better characterization of metals, pesticides, and PCBs in Nanticoke watershed. (2.3.5.2 #2,#5,#10,#15)
- Identify intensive ground-water extractive use in areas that may have water availability issues. (2.5.4 #8)
- The location of all facilities with water allocations should be updated and a coverage created in the Department GIS similar to that created for public supply wells. (2.5.4 #2,#3)

**Low Priority — Surface Water, Ground Water, and Wetlands:**

**Type I**
- Accurately define all sub-cropping aquifer areas to help protect the deeper portions of these aquifers. (2.5.4 #9)
- Better mapping accuracy for surface-water intakes including all irrigational uses. (2.5.4 #2,#3,#14)

### 3.2.2.2 Living Resources

In many ways, our living resources reveal more about the state of our environment than any other factor. Our native species are generally the first indicators of change or disruption. They experience first-hand the direct impact of habitat loss, degraded air and water quality, and competition from exotic species. In particular, studies of rare and declining species can play special roles as environmental indicators. These are often the species most sensitive to environmental change and habitat degradation, and hence can bring the first hints of environmental impact. With development pressure increasing, it becomes more urgent that these sensitive living resources be accurately characterized throughout the Basin.

**Recommendations — Living Resources**

**High Priority — Living Resources:**

**Type I**
- A survey of the Chesapeake Basin should be conducted as soon as possible to identify remaining upland forests and to evaluate the quality of these areas using such factors as biodiversity, size, age, and exotic infestation. Appropriate actions should then follow such as natural area designation for qualifying tracts, legal protection, and/or restoration. (2.7.7 #1)
- A survey of rare habitats should be conducted and summarized. Appropriate actions should be taken to protect these areas, including natural area designation for qualifying tracts, legal protection, and/or restoration. (2.7.7 #2)
- Critical spawning habitat in the Nanticoke River should be identified through subaqueous mapping and available fish sampling data. Once identified, these areas should be afforded protection from excess siltation, dredging, and water-quality degradation. (2.7.7 #14)
- Once high-quality freshwater mussel sites have been identified, they should be afforded protection from habitat degradation. (2.7.7 #15)
- Work cooperatively with adjacent states to identify the status of the American eel fishery. (2.7.7 #11)
- Incorporate Delaware Natural Heritage Program databases with other planning databases, including those in Maryland, so that rare species are identified prior to development. (2.7.7 #18)

**Medium Priority — Living Resources:**

**Type I**
- Little information is known about the status of many native fishes (mostly non-game species). More data need to be collected on the presence and population levels of these native species. (2.7.7 #20)
- Data on spawning locations, spawning success, population structure, and population levels for yellow perch need to be collected. (2.7.7 #21)
**Low Priority — Living Resources:**

**Type I**
- Delaware should contact the Army Corps of Engineers and ask them to summarize the nature and extent of shipping activity on the Nanticoke. (2.3.5.2 #6)

**Type II**
- A test-scale controlled burn should be conducted on fire-dependent plant communities to re-establish the link between fire and the natural diversity and adaptability of the extant species in Delaware’s modern forests and marshes. (2.7.7 #10)
- Acquired the resources necessary to study and quantify the level of ozone-induced crop damage and its associated impacts. (2.4.4 #4)
3.3 NON-NUTRIENT CONTAMINANTS

Chemical contamination from “classic” industrial sources and the potential threat of this contamination is not widespread in the Chesapeake Basin. The highest concentration of these sites occurs within, and immediately surrounding, the towns located in Sussex County. Leaking underground storage tanks (LUSTs) make up a majority of the sites with known contamination. Petroleum hydrocarbons are the chemical contaminants that most often are associated with these LUST sites. Contamination of nearby drinking wells is the most common concern regarding this type of contamination. Besides the LUST sites, there are a number of contaminated sites located throughout the Basin that are managed by other programs within the Department. For instance, the Site Investigation and Restoration Branch oversees the abandoned Sussex county landfills, while the Ground Water Discharges Section monitors community septic systems.

Chemical contamination from the use of agricultural pesticides and herbicides has not been fully characterized in the Chesapeake Basin. Also, there may be some legacy issues surrounding contaminated sediments of the Basin’s waterways; however, these are not adequately characterized either. While chemical contamination is of much less concern than the nutrient contamination that affects the Chesapeake Basin, existing data gaps inhibit the Department’s ability to definitively characterize the issue of Basin-wide chemical contamination at this time.

3.3.1 RESEARCH AND INVESTIGATION

3.3.1.1 Department Policy and Future Direction

Recommendations — Policy

High Priority — Policy:

Type I

- The extent to which metals contamination of the sediment is also a problem in the water column is not well characterized. Historical water column metal data should be compiled and assessed in conjunction with the Preliminary Assessment Report. (2.3.5.2 #10)

- The results of the Chesapeake Bay Fall Line Toxics Monitoring Program for the Bridgeville USGS gauge location suggest existence of sources for pesticides and metals entering the Nanticoke River above the Bridgeville gauge. The Chesapeake Whole Basin Team should review and map out available pollutant source data for that area of the watershed above the Bridgeville gauge. The relative importance of these sources in comparison to sources in the Seaford area should be considered within an overall mass balance context. (2.3.5.2 #4)

Type II

- Due to the regional nature of the ozone problem, it is essential that we continue to participate with other states, regional and federal agencies on data sharing efforts. Delaware currently works with, and should continue to work with, other states, regional agencies and EPA to communicate ozone data between the various states and agencies. (2.4.4 #2)

- The Department should coordinate with the U.S. EPA and the City of Seaford in the review of influent and effluent data generated in conjunction with the city’s Industrial Pretreatment Program for its wastewater treatment plant. The effluent data should be used to estimate mass loadings of toxics to the Nanticoke River from the treatment plant. (2.3.5.2 #1)

Medium Priority — Policy:

Type I

- A sediment “Triad” study should be conducted in the reach of the Nanticoke River below Seaford to confirm or refute whether the sediments are actually toxic to benthic organisms. (2.3.5.2 #14)

- Deep (e.g. 3 to 5 feet) sediment cores should be obtained and analyzed at discrete depth intervals in an effort to determine the historical input and sedimentation rate of PCBs and heavy metals in the Nanticoke below Seaford. (2.3.5.2 #15)

- Educate the public regarding the proper disposal of motor oil and household chemicals. Continue to support the efforts of the Delaware Solid Waste Authority in its household hazardous waste collection program. (2.3.5.2 #8)

- Adequate information currently exists to evaluate status and trends for the criteria pollutants: volatile organic compounds, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead. Data collection and evaluation should continue unchanged. (2.4.4 #1)

- The periodic ozone precursor emission inventories for VOCs, NOx, and CO are compiled every three years. The inventories are comprehensive and cover all emission source categories. Emission inventories for SO2, PM10, TSP, lead, and toxics are performed annually but only for large point sources. More comprehensive inventories of these pollutants with the addition of PM2.5 are recommended in order to gain
additional information on impacts to the Chesapeake and other basins. Impacts of emissions on the Chesapeake and other basins could also be improved by developing methods to enable aerial, mobile, and biogenic emissions to be illustrated in graphical form, such as on a Geographic Information System (GIS) map. (2.4.4 #4)

- Explore options for acquiring the needed support to produce comprehensive periodic inventories of SO₂, PM₁₀, TSP, lead, and toxics. (2.4.4 #4a)
- Explore options for acquiring the needed support to produce comprehensive periodic inventories of greenhouse gases. (2.3.5.2; #17)
- Develop a method to allocate area, mobile and biogenic emissions to geographic basins, and graphically portray those emissions. (2.4.4 #4b)
- The Department should evaluate the extent to which Best Management Practices are being implemented for bulk chemical transfer and storage along the Seaford waterfront. (2.3.5.2 #7)
- Adequate information currently exists to evaluate the status and trends for PM₁₀. New particulate matter standards for PM₂.₅ have been enacted by EPA and require the development of baseline data from which future reductions may be calculated. (2.4.4 #3)
- Develop a combined strategy to coordinate groundwater sampling and share analytical data. (2.5.4 #1)

3.3.2 EDUCATION AND PROTECTION
3.3.2.1 Department Policy and Future Direction

**Recommendations — Policy**

**High Priority — Policy:**

**Type I**

- Place EPCRA Tier II facilities on the chemical contaminants map and also populate the Site Index Database with these sites. (2.3.5.2 #9)
- Provide technical assistance to the City of Seaford for the installation of “urban BMPs” such as sand filters and other passive storm-water pollutant reduction devices. (2.3.5.2 #11)
- Aboveground storage tanks are currently unregulated; develop regulations for operation, spill/overfill protection, leak detection, tank testing requirements, and corrosion protection. (2.3.5.2 #13)

**Type II**

- The Department should continue to work with the City of Seaford to ensure that the city’s Combined Sewer Overflows (CSOs) are eliminated in a timely manner. (2.3.5.2 #3)

**Medium Priority — Policy:**

**Type I**

- Develop education process for owners of exempt Underground Storage Tanks about proper maintenance and leak detection to avoid become a regulated LUST. (2.3.5.2 #16)

3.3.2.2 Implemented Projects and Pollution Control Strategies

The Chesapeake Team recognized the need for increased public awareness about Basin-wide environmental issues. The idea for placing street signs stating that you are entering the Basin was brought forward along with a Basin-wide storm-drain stenciling project. The Inland Bays/Atlantic Ocean team moved forward on the Basin project with the idea that the other basins will follow. The Chesapeake team help provide the information necessary to incorporate the storm-drain stenciling into the state’s middle school Watershed Education Curriculum.

**Recommendations — Implemented**

**High Priority — Implemented:**

**Type I**

- Implement a storm-drain stenciling program to raise the awareness of the public concerning the relationship between storm-water runoff and river quality. (2.3.5.2 #12)