# APPOQUINIMINK RIVER
# POLLUTION CONTROL STRATEGY

**NOVEMBER 2010**

# TABLE OF CONTENTS

# FOREWORD

This document details a Pollution Control Strategy (Strategy) for Delaware's Appoquinimink River and its tributaries. It was developed through a collaborative public process involving multiple interests in the watershed. The Appoquinimink Tributary Action Team (Team), comprised of local government representatives, business people, environmentalists, teachers, farmers and residents, gathered to give their input during several meetings and develop a recommended strategy to achieve State Water Quality Standards for dissolved oxygen and nutrients (nitrogen and phosphorus) and protect the designated uses of the waters of the Appoquinimink. The Team provided their Strategy to the Delaware Department of Natural Resources and Environmental Control (Department) and recommended implementation of its elements.

Various organizations provided the assistance to the Department in assigning nutrient load reduction efficiencies to various Best Management Practices (BMPs) through the Pollution Control Strategy Workgroup, a collection of representatives from Soil and Water Conservation Districts, the Delaware Nutrient Management Commission, the University of Delaware and various Department programs.

Based on the recommendations from these groups, the Department now proposes this Pollution Control Strategy for the Appoquinimink River and its tributaries. The Department wishes to thank the residents who volunteered thousands of hours towards the development of a Pollution Control Strategy through their participation on the Appoquinimink Tributary Action Team and with the Appoquinimink River Association. The Department also wishes to recognize and thank the multiple agencies, programs, and local governments that participated in the effort.

# EXECUTIVE SUMMARY

Total Maximum Daily Loads (TMDLs) are the maximum amount of a pollutant that a waterbody can assimilate and still achieve water quality standards. They were established for the entire Appoquinimink River in December, 2003 (Appendix A). These TMDLs called for a 60% reduction in nonpoint nitrogen and phosphorus loading. An implementation plan, or a Pollution Control Strategy (Strategy), was to be developed by a Tributary Action Team, a diverse group of citizens and government agency personnel and presented to the Department for promulgation to reach the prescribed TMDLs (Appendix B). This document reflects those recommendations made by the Appoquinimink Tributary Action Team (Team) based on a consensus-seeking process.

The process used to generate this Strategy, "*Public Talk-Real Choices*", places importance on putting the public first in policy-making (Appendix C). The Tributary Action Team recommended a Pollution Control Strategy, a set of actions for achieving the TMDL, to the Department. This Strategy is based on general principles developed by the Team after a public forum and many meetings. These principles, or common ground, are the foundation that the Team used in building their Strategy. The following guiding principles were discussed and agreed upon during the June 2001 public forum. These principles served to guide the writing of the actions within the Pollution Control Strategy.

- Concurrence of all applicable laws, regulations and ordinances are needed to achieve the TMDL.
- Regulation must be fair and reasonable; rules must apply to everyone equally.
- Watershed residents need to be informed as to the problems and solutions of water quality. (education)
- Participation by residents will be necessary in order to achieve the required nutrient reductions.
- We need to use a combination of policy and management tools in the PCS.
- There needs to be a mechanism in place that measures progress towards achieving water quality goals and communicates it to the public at regular intervals.

The Strategy itself addresses several areas for nutrient loading reduction with nonpoint sources of pollution:

- Agriculture
- Development
    - Stormwater
    - Impervious Cover Limits

- Conservation Design
- Open Space

- Wastewater
    - Inspection/Replacement
    - Performance Standards
    - Education

- Residential Behavior

The Strategy is designed to reduce nutrient loadings from current and future land practices. This combination of actions will lead to the achievement of the TMDL.

Scientific literature and experts in the pertinent fields were consulted and assisted the Department in estimating the nutrient reductions that would be achieved through the promulgation of this Strategy. These estimates are shown throughout this document and specific documentation is provided in Appendix D. In addition, the Strategy reviews the various costs associated with the recommended actions in Appendix E. The Strategy also recommends funding mechanisms and implementation schedules, where appropriate, as well as identifies responsible parties. Finally, the strategy reviews the agencies and programs that are charged with implementing elements of the Strategy.

The Department intends to review the Strategy in ten years to assure progress towards achieving water quality standards. Table 1 summarizes the various actions considered in this Pollution Control Strategy.

Table 1: Pollution Control Strategy Action Items

| *PCS Action* | *Path Towards Implementation* |
|---|---|
| **Agriculture** | |
| The State should continue funding nutrient management planning. | **Voluntary** |
| The State should continue funding agricultural best management practices to ensure maintenance of current levels of implementation. | **Voluntary** |
| The County and State should continue their efforts to preserve farmland in the Appoquinimink watershed. | **Voluntary** |
| A recognition program should be created for farmers in the Appoquinimink watershed who do the most to protect water quality. | **Voluntary** |

| **Development** | |
|---|---|
| The State should promulgate minimum standards for nutrient reduction as they relate to development. The County and local governments should enact ordinances that will achieve those standards within one year of the promulgation of the PCS. | **Voluntary** |
| State, county and local governments should coordinate efforts with nonprofit organizations to provide an ongoing environmental education and outreach program for residents. | **Voluntary** |
| ***Stormwater*** | |
| All permanent sediment and stormwater management plans should be designed and implemented to include criteria that will reduce nutrient loading by the percentage required to meet TMDL-required nutrient load reductions of ground and surface waters to the maximum extent practicable. | **Regulatory – To be included in the updated State Sediment and Stormwater Regulations** |
| Local governments should establish a community stormwater runoff education and stormwater management area maintenance program for the watershed to provide resources to educate homeowners, homeowners' associations (HOAs), and groups that maintain stormwater structures. | **Voluntary** |
| Within 6 months from the promulgation of the PCS, DNREC should convene a group composed of representatives from the community and local, county, and state government to establish a stormwater retrofit process for the Appoquinimink watershed. | **Voluntary** |
| Encourage the creation of a stormwater utility pilot project in the Appoquinimink watershed. | **Voluntary** |
| ***Impervious Cover Limits*** | |
| The State should promulgate a watershed-wide limit for impervious coverage with consideration for site-specific mitigation and emphasis on water resource protection areas. | **Regulatory – To be included in the updated State Sediment and Stormwater Regulations** |
| Government entities should provide developers suggestions and incentives for use of alternative pervious materials and strategies for sidewalks, parking lots and roadways. | **Voluntary** |

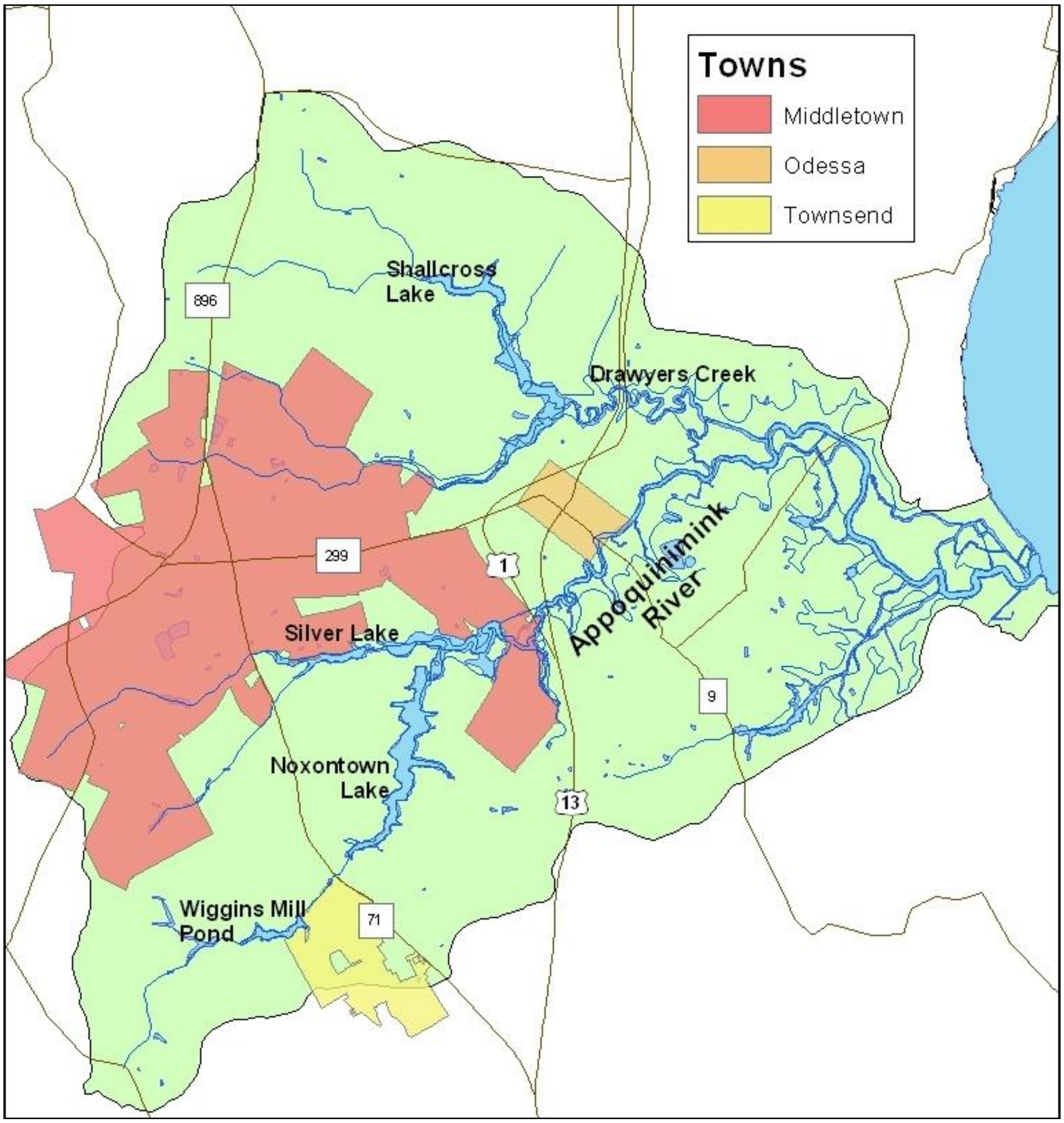
| | |
|---|---|
| ***Conservation Design*** | |
| State, county, and local governmental bodies should better define the concept of "conservation design" and enact codes and regulations that allow for and promote "conservation design" principles with the goal of reducing nutrient loads. | **Voluntary** |
| ***Open Space*** | |
| All open space land uses should be designed and managed for water quality protection, including reduced nutrient loading. Reforestation, meadow development, wetlands construction, and other natural resource preservation should be encouraged through increased outreach efforts by the appropriate jurisdictions and local nonprofit organizations. | **Voluntary** |
| Incentive efforts to better manage residential open spaces should be better publicized to residents and maintenance corporations in order to support enhancement of the open spaces. | **Voluntary** |
| **Wastewater** | |
| Seepage pits and cesspools should be prohibited within the watershed. | **Regulatory – To be included in the updated State Regulations Governing the Design, Installation, and Operation of Onsite Wastewater Treatment and Disposal Systems** |
| Existing holding tanks must be operated in accordance with their permits and their conditions. In instances where central sewer service will become available within five years, temporary holding tanks will only be permitted after the Department receives a letter (with an approved Certificate of Public Convenience and Necessity (CPCN), where applicable) stating when central sewer will become available from New Castle County, the appropriate local government, or the wastewater utility. | **Regulatory – To be included in the updated State Regulations Governing the Design, Installation, and Operation of Onsite Wastewater Treatment and Disposal Systems** |
| No new drainfields may be present within 100 feet of perennial and intermittent streams, lakes, and wetlands. | **Regulatory – To be included in the updated State Regulations Governing the Design, Installation, and Operation of Onsite Wastewater Treatment and Disposal Systems Regulations** |

| | |
|---|---|
| ***Inspection/replacement*** | |
| All properties utilizing an OWTDS that are sold or otherwise transferred to other ownership shall have their systems pumped out and inspected prior to the completion of the sale. These requirements can be filled by supplying (1) the certificate of completion, (2) documentation of a pump out and inspection within the previous 36 months, or (3) proof of a licensed operator or an annual service contract with a certified service provider. | **Regulatory – To be included in the updated State Regulations Governing the Design, Installation, and Operation of Onsite Wastewater Treatment and Disposal Systems** |
| Convert as many lots as feasible (of less than 2 acres each) currently on septic to sewer connection in an equitable manner whereby those systems of high priority and feasibility (where there is already infrastructure in place) are converted first. The State and DNREC should provide cost share and grant monies to these homeowners to help offset costs. | **Voluntary** |
| ***Performance Standards*** | |
| All new and replacement onsite wastewater disposal systems must be designed to achieve performance standards as specified in the updated State Regulations. To provide proper operation and maintenance of the innovative and alternative onsite wastewater treatment and disposal system, the permittee is required to adhere to Department permit conditions. These permit conditions require mandatory operation and maintenance for the life of the system by maintaining a service contract with a certified service provider. | **Regulatory – To be included in the updated State Regulations Governing the Design, Installation, and Operation of Onsite Wastewater Treatment and Disposal Systems** |
| ***Education*** | |
| The State, County and local governments should work together to develop and disseminate homeowner education materials. The materials should inform septic system owners about proper maintenance of their septic systems, and be based on the system type that is used, such that nutrient loading from the system is minimized. The materials should emphasize the dual benefits of proper system maintenance to both homeowner and watershed. | **Voluntary** |

| | |
|---|---|
| **Residential Behavior** | |
| Establish guidelines that promote good lawn and yard stewardship through best management practices, including organic methods of care, for better nutrient management and water quality. | **Voluntary** |
| The State should work with the University of Delaware Soils Lab to revise the soil test result sheets that go to homeowners in order to make them more understandable and easily implemented by the lay public. The State should also work with the Cooperative Extension Service to assist in disseminating soil test kits. | **Voluntary** |
| Local governments should develop appropriate code changes and distribute guidelines, through consultation with the State, for alternative lot landscaping that will reduce surface water runoff. Information should be given to homeowners at the time of settlement. | **Voluntary** |
| Explore the possibility of providing nutrient management education and training for those who sell fertilizers in retail outlet. This would include working with retailers to see that a stick-on label be placed on all bags of fertilizers sold in the watershed warning that the overuse or improper use of fertilizers harms our ground and surface waters. | **Voluntary** |
| All environmental information should be supplied periodically on the scrolling band under the picture on the Weather Channel. DNREC should find the money to pay for this if cable providers will not do it as a public service. | **Voluntary** |
| The County and State should re-establish a groundwater monitoring program for southern New Castle County to ensure the quality of our drinking and surface water. | **Voluntary** |

# BACKGROUND

The Appoquinimink River Watershed drains approximately 30,200 acres (47 sq miles) of coastal plain farmland in southern New Castle County, as well as the urbanized areas of Middletown, historic Odessa, and Townsend before discharging into the Delaware Bay. The topography is generally characterized by flat to gently sloping land which is typical of the coastal plain. The upland portion of the watershed is generally flat, but steep slopes can be found associated with stream valleys in the headwaters.




Notably, the expansive tidal wetlands at the mouth of the Appoquinimink River in conjunction with the Blackbird River to the south represent one of the largest undisturbed marsh systems in Delaware. These wetlands serve as important habitat for wildlife and waterfowl, spawning grounds for fish and other aquatic species, and passive recreation for local birdwatchers at the St. Augustine Wildlife Area.

Noxontown Pond, Shallcross Lake, Silver Lake, and Wiggins Mill Pond are the four largest freshwater impoundments in the watershed. The Appoquinimink River is tidal from the confluence with Delaware Bay to the dam at Noxontown Lake on the main stem, the dam at Silver Lake on Deep Creek, and the confluence with Drawyers Creek. Salinity intrusion from Delaware Bay typically reaches upstream past the Drawyers Creek confluence at river kilometer (Rkm) 8.5.

In addition to surface waters in the Appoquinimink watershed, groundwater plays an important role throughout the area. Groundwater is found within the surficial Columbia aquifer that is recharged directly by rainfall where soil permeability is high. Deeper groundwater aquifers commonly used for well water are recharged from upgrade areas of the County (TRC, 2004). Due to the highly permeable soil conditions, 30% of the upland area in the watershed has been designated by the Delaware Geological Survey (DGS) as a Water Resource Protection Area (WRPA). In these areas, subsurface flow can supply a significantly larger portion of water to surface streams than overland runoff (TRC, 2004).

## LAND USE

More than half of the watershed is actively cultivated; however, as development spreads south of the Chesapeake and Delaware canal, these farmlands are rapidly converting into suburban residential uses.

Impervious cover is a revealing indicator of the extent and pattern of growth in the watershed. In 1992, watershed impervious cover was estimated to be 4%, but grew to 9% in 2007, and is projected to reach a maximum of 25% in the future. Hydrologic changes resulting from the urbanization of agricultural lands may result in increased flooding, channel erosion, and water quality impacts in the watershed (CWP, 2005b).

Less than 9% of the watershed remains forested, dominated by oak, hickory, pine, and species common to southern floodplain and mixed forest assemblages. Most forested areas are located along the stream valley, and very few large contiguous tracts of un-fragmented forest remain in the watershed (CWP, 2005b).

In 1992, less than 12% of the watershed was classified as urban land and the majority of the land was used for agriculture (63%). Based on 2002 land use data, just over half of the watershed was in agricultural use (51%) and almost a quarter of the watershed was classified as urban uses (20%). Current land use estimates from 2007 data show that the land use of the Appoquinimink continues to change with 27% of the land now considered urban and 42% agricultural. Table 2 summarizes the land use change in the Appoquinimink Watershed.

Table 2: Land Use Changes in the Appoquinimink Watershed

| | *Urban* | *Agriculture* | *Water* | *Wetland* | *Forest* | *Other* |
|---|---|---|---|---|---|---|
| *1992* | 11% | 62% | 4% | 13% | 9% | 1% |
| *1997* | 13% | 59% | 4% | 13% | 9% | 2% |
| *2002* | 20% | 52% | 4% | 13% | 8% | 3% |
| *2007* | 27% | 42% | 5% | 13% | 8% | 5% |

(Note: The category "Other" is made up of rangeland and barren lands which include the land found under utility lines.)

## WATER QUALITY

The Appoquinimink River watershed has historic water quality problems with respect to nutrient and low dissolved oxygen concentrations. The aquatic ecosystem is most sensitive to water quality impairments during the summer months given the combined effects of low sediment oxygen demand levels induced by pollutant loads, hydrodynamics such as tidal influences, and the fact that oxygen becomes less soluble as water temperature increases (USEPA, 2003).

Historically, pollution from the agricultural land base, followed by septic systems and the Middletown-Odessa-Townsend Wastewater Treatment Plant (MOT WWTP) were the major contributing sources of nutrients within the watershed (Ritter and Levan, 1993). It was estimated that more than 75% of the nitrogen (N) and phosphorus (P) load was from cropland, whereas the WWTP largely made up the remaining P load. Septic systems contributed a minimal amount of P, but had the potential to have a large impact on the N load (Ritter and Levan, 1993).

Since that time, both direct and indirect measures have contributed to a decrease in nutrient loadings to the watershed such as the implementation of agricultural best management practices (BMPs) and a change from septic to sewered urban areas. However, at the same time nutrient loadings have increased from previously unimportant sources including nonpoint sources. Pollutant loads not associated with discrete discharges are categorized as nonpoint sources. In contrast to continuous discharge from treatment plans, loading from nonpoint sources is typically intermittent, diffuse, and difficult to track back to specific sources. Nonpoint sources of pollution can come from most land uses through overland flow. However, nonpoint source pollution can also leach into ground water and subsequently enter surface water. Major land use changes have recently occurred and continue to occur within the watershed as more agricultural land is converted to medium and high-density residential suburban land use.

The only non-stormwater point source in the watershed is the Middletown-Odessa-Townsend wastewater treatment plant (MOT WWTP). Although the MOT WWTP primarily uses spray irrigation to dispose of its effluent, it is also permitted to discharge to the surface waters of the Appoquinimink River (CWP, 2005b).

The Appoquinimink River currently is designated as a warm-water fishery and is subject to all water quality criteria specific to this designated use and those defined for general statewide water uses including primary and secondary contact recreation; fish, aquatic life, and wildlife; and industrial and agricultural water supply. Several stream segments of the Appoquinimink River basin have been cited on the State’s 303(d) list of impaired waters for failing to attain their applicable criteria (DNREC, 2004).

In addition, the DGS reports water quality in most of the groundwater aquifers in the watershed as being “primarily calcium magnesium-bicarbonate type water indicating an anthropogenic/agricultural influence.” Nitrate levels greater than natural background levels and pesticides were detected in most of the samples from the shallow aquifers. Of the 16 wells sampled in the Appoquinimink, 11 showed nitrate levels above 0.4 mg/L (background level), mostly in the shallow and unconfined aquifers (CWP, 2005b).

## OVERVIEW OF THE TOTAL MAXIMUM DAILY LOAD (TMDL)

Section 303(d) of the Clean Water Act requires states to identify water quality impaired waterways and to develop Total Maximum Daily Loads (TMDLs) for the pollutants that impair those waterways. As such, the Division of Water Resources (Division) determined that the water quality of the Appoquinimink River, and its tributaries are impaired by elevated nutrient levels and low dissolved oxygen concentrations. Symptoms of nutrient enrichment include excessive algae growth, large daily swings in dissolved oxygen levels, loss of submerged aquatic vegetation, reduced populations of fish, shellfish, and other aquatic life, and fish kills. These symptoms threaten the future of the Appoquinimink River and its significant natural, ecological, and recreational resources, which may result in adverse impacts to the local and State economies through environmental degradation and habitat loss leading to reduced tourism, a decline in property values, lost revenues and a diminished quality of life. Hence, excessive nutrient levels pose a significant threat to the health and well being of people, animals, and plants living within the watershed.

An initial TMDL was prepared by DNREC in 1992 for the Appoquinimink to limit phosphorus loadings to the basin, but was limited to the upper freshwater tidal and lower tidal segments of the Appoquinimink River. As a result of the persistent water quality problems within the watershed, a TMDL was adopted by EPA Region III and DNREC for the Appoquinimink River on January 30, 1998 that expanded the geographic extent and water quality impairments of the 1992 TMDL. The 1998 TMDL addressed water quality impairments due to low dissolved oxygen concentrations violating the water quality standard of 5.5 mg/L. Additional TMDLs were developed for the remaining tributaries and ponds within the Appoquinimink River Basin. These segments were identified as impaired waters on the Delaware’s 1996, 1998 and 2002 Section 303(d) lists for their failure to protect aquatic life due to violations of the water quality standard for dissolved oxygen, or nutrients.

In December 2003, EPA approved a TMDL for nutrients and dissolved oxygen impairments for the entire Appoquinimink watershed (Appendix A). In order for the Appoquinimink River to meet water quality standards, the TMDL calls for a 60% reduction in nutrient loadings from the land area within the watershed. The implementation tool was to be a Strategy initiated by the Department and developed by the public through the Appoquinimink Tributary Action Team. In total, the actions within the Strategy must achieve a reduction in nitrogen of 890.83 lb/day and 23.50 lb/day of phosphorus loading (Figures 1 and 2).

While point sources of pollution including the Middletown-Odessa-Townsend Wastewater Treatment Plant were included in the Appoquinimink TMDL, the data did not show reductions needed from the current loads allowed by the plant’s stormwater permit.

Figure 1: Total Phosphorus Load Reductions Required by the TMDL

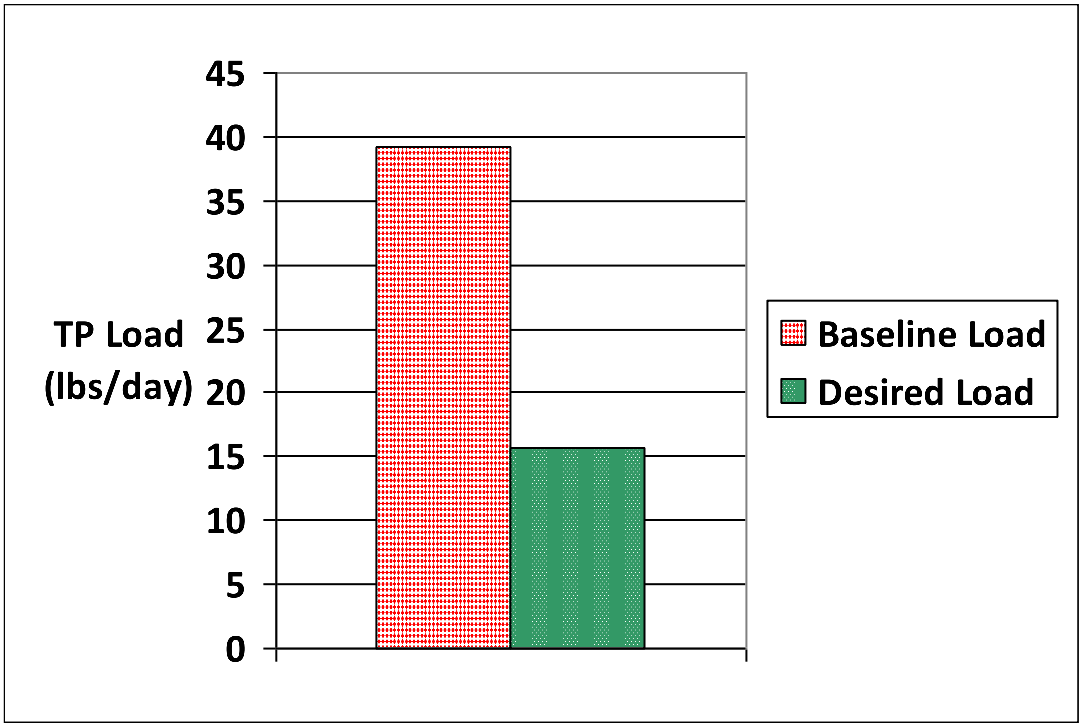
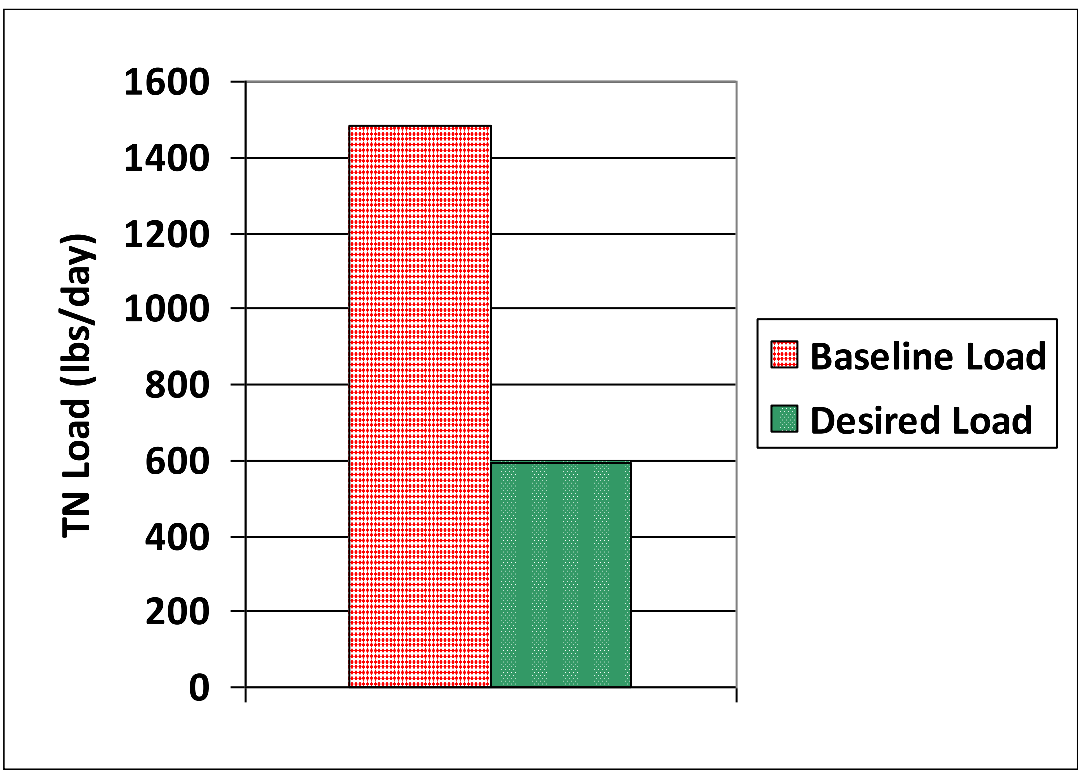



Figure 2: Total Nitrogen Load Reductions Required by the TMDL



## THE POLLUTION CONTROL STRATEGY DEVELOPMENT PROCESS

In 2000, The Delaware Department of Natural Resources and Environmental Control (DNREC) approached the Appoquinimink School District's Science Curriculum Coordinator in order to solicit her assistance in forming and facilitating a Tributary Action Team (Team) for the Appoquinimink watershed. This Team was tasked with recommending a Pollution Control Strategy (PCS) to DNREC for meeting the nutrient and dissolved oxygen Total Maximum Daily Load (TMDL) established by EPA in January 1998 (for the tidal portion) and to meet the future TMDL for the tributaries. In December 2003, another TMDL (Appendix A) was established by EPA that included the entire watershed and required a more stringent reduction in nutrient loads. With the creation of the nonprofit organization the Appoquinimink River Association in April 2004 by members of the Team, they too became involved with creating additional recommendations to help strengthen the Pollution Control Strategy. This PCS recommends actions which will work towards achieving a 60% reduction in nonpoint source nutrient loadings to the River and its tributaries. It is based upon the guiding principles that were gleaned from a June 2001 public forum as well as meetings of the Association's Pollution Control Strategy Subcommittee in 2004 and 2005. The principles developed during this process include the following:

- Concurrence of all applicable laws, regulations and ordinances are needed to achieve the TMDL.
- Regulation must be fair and reasonable; rules must apply to everyone equally.
- Watershed residents need to be informed as to the problems and solutions of water quality. (education)
- Participation by residents will be necessary in order to achieve the required nutrient reductions.
- We need to use a combination of policy and management tools in the PCS.
- There needs to be a mechanism in place that measures progress towards achieving water quality goals and communicates it to the public at regular intervals.

Although changes have been made, this Strategy is substantially based upon the recommendations offered by the Team (Appendix B). The contents of this document are based on those recommendations. The document presents the Pollution Control Strategy as well as provides technical justification for its elements.

## PROGRESS TO DATE

Eight years have passed since the TMDL for the Appoquinimink River was promulgated based on 1992 pollution levels. Since that time, population and pressures from development have increased throughout the watershed. However, stormwater and wastewater have improved and farmers have increased their use of best management practices (BMPs). Increased use of BMPs in all sectors reduces nutrient loading and contributes to progress towards achieving water quality standards.

Estimated water quality improvement from the installation of best management practices, after the TMDL baseline, was calculated. Various databases were used to gather the number of practices in place. Scientists researched the nutrient load reduction efficiencies associated with these practices in order to estimate pollution reductions. Appendix D documents those calculations and Appendix E estimates the associated costs.

### *Agriculture*

Since the baseline period, the agricultural community has reduced a significant amount of nonpoint source nitrogen and phosphorus, leading the efforts to curtail nonpoint source loadings. From the baseline to 2008, multiple BMPs have been implemented and the Delaware Nutrient Management Act was passed. As of January 2007, all farms that apply nutrients to 10 acres or more are required to have Nutrient Management Plans (NMPs). Subsequent Farm Bills have also led to increased funding levels of cost-share programs for BMPs that protect the environment, especially water quality.

Table 3: Implemented Agricultural Best Management Practices (BMP)

| | *Acres* | *TN reduced (lb/day)* | *TP reduced (lb/day)* |
|---|---:|---:|---:|
| *Cover Crops* | 3,145 | 118.25 | 0.25 |
| *Ponds* | 3 | 0.11 | 0.00 |
| *Grassed Waterways* | 3 | 0.12 | 0.00 |
| *Grassed Filter Strips* | 20 | 0.82 | 0.01 |
| *Wildlife Habitat* | 1,414 | 58.10 | 0.77 |
| *Grassed Filter Strips* | 54 | 5.62 | 0.13 |
| *Forest Buffers* | 55 | 7.64 | 0.16 |
| *Riparian Buffers* | 5 | 0.67 | 0.01 |
| *Wetlands* | 2,461 | 343.91 | 7.38 |
| *Field Border (feet)* | 18,299 | 0.35 | 0.00 |
| *Critical Area Planting* | 36 | N/A | 0.00 |
| *Conservation tillage* | 4,182 | N/A | 0.01 |
| *Nutrient Management Plans* | 12,584 | 137.90 | 4.14 |

Total Progress to Date:

Estimated Nutrient Reductions: 673.49 lbs/day TN; 12.88 lbs/day TP

Estimated Full Strategy Implementation Cost: $24,201,000

*Open Space*

New Castle County and the local governments located in the Appoquinimink Watershed have furthered nutrient reductions by making open space and riparian buffer preservation a priority in these developing communities. By setting aside area during the development process that must remain grassed open space and protecting areas that are within the riparian buffer area, these entities are helping to protect waterways from nutrient pollution. In total, there are 1,256.67 acres of grassed open space preserved in the development process as well as 1,972 acres of riparian buffer preserved.

Total Progress to Date:

Estimated Nutrient Reductions: 260.19 lbs/day TN; 5.76 lbs/day TP

Estimated Full Strategy Implementation Cost: $6,631,000

*Onsite Wastewater*

Current septic system pump outs and conversion of onsite wastewater systems to central sewer systems, while not extensive, has helped to decrease the nutrient pollution entering the Appoquinimink watershed. An estimated average of 100 septic systems in the watershed are currently being pumped out a year while 11 properties in the watershed have been converted from septic systems to central sewer systems.

Total Progress to Date:

Estimated Nutrient Reductions: 1.04 lbs/ day TN; 0.24 lbs/day TP

Estimated Full Strategy Implementation Cost: $21,669,000

*Stormwater*

In June 1990, the Delaware Legislature passed the Sediment and Stormwater Law to help correct the State's water quality and quantity problems. The implementing program was initiated in July of 1991 and addresses sediment control during construction and post-construction, stormwater quantity and water quality control. Since this implementation, many BMPs for stormwater have been implemented and more are constructed each year. The Sediment and Stormwater Regulations are currently being revised to promote the use of stormwater management techniques that are more efficient at reducing nutrient loading and promote Green Technology BMPs or stormwater management practices based on low impact development and conservation design.

Table 4: Total Stormwater BMPs Implemented to Date

| *BMP* | *Acres* | *TN Reduced (lb/day)* | *TP Reduced (lb/day)* |
|---|---|---|---|
| *Dry Pond* | 566 | 3.49 | 0.184 |
| *Wet Pond* | 5,861 | 28.91 | 4.195 |
| *Filtering Practice* | 10 | 0.16 | 0.008 |
| *Infiltration Practice* | 86 | 2.31 | 0.079 |
| *Open Channel Practice* | 180 | 1.85 | 0.068 |
| *DelDOT Rt. 1 Practices* | Not available | 2.76 | 2.58 |

Total Progress to Date:

Estimated Nutrient Reductions: 39.47 lbs/day TN; 7.11 lbs/day TP
Estimated Full Strategy Implementation Cost: $160,632,000

*Overall Nutrient Load Reduction Progress*

All sectors have taken steps to improve water quality through the implementation of laws, regulations, and voluntary BMPs. Analysis using a basic land use loading rate model shows that, to date, nonpoint sources of TN and TP have been reduced by 109% and 111%, respectively, from the TMDL baseline levels. While land use modeling based on current practices predicts reductions exceeding that required by the TMDL, there is still a need for further reductions in areas that are currently lacking such as wastewater and stormwater. The total reduction and costs are discussed in more detail in the section entitled, "Analysis for TMDL Achievement and Costs".

## AUTHORITY

The authority to create a Strategy comes from the Delaware Code, Title VII, Chapter 60. The General Assembly found multiple reasons why regulation of natural resources was needed including recognizing that "[t]he regulation of the development and utilization of the land, water, underwater and air resources of the State is essential to protect beneficial uses and to assure adequate resources for the future" (7 Del. Code §6001 (a)).

The related policies and purposes are also broad in their coverage (§6001 (b,c)). Section 6010 (a) states that the "Secretary may adopt, amend, modify or repeal rules or regulations, or plans, after public hearing, to effectuate the policy and purposes of this chapter." Thus, control of pollution and protection of resources are legitimate regulatory goals.

Article 5 of the TMDL for the Appoquinimink River regulation requires the development and implementation of an implementation plan. Additionally, the State Water Quality Standards state that all "human induced nonpoint sources, subject to control through the use of best management practices or otherwise, shall be required to remove nutrients to the extent necessary to prevent excessive growth of photosynthetic organisms." The TMDL has determined that level, and this Strategy outlines the actions for achieving that level of water quality.

# THE POLLUTION CONTROL STRATEGY

To guide the writing of the actions within this Pollution Control Strategy (Strategy), the Appoquinimink Tributary Action Team (Team) adhered to the following guidelines:

- Concurrence of all applicable laws, regulations and ordinances are needed to achieve the TMDL.
- Regulation must be fair and reasonable; rules must apply to everyone equally.
- Watershed residents need to be informed as to the problems and solutions of water quality. (education)
- Participation by residents will be necessary in order to achieve the required nutrient reductions.
- We need to use a combination of policy and management tools in the PCS.
- There needs to be a mechanism in place that measures progress towards achieving water quality goals and communicates it to the public at regular intervals.

This Strategy is divided into four sections each outlining the voluntary and regulatory actions needed to achieve nonpoint source pollution reductions in the following areas:

- Agriculture
- Development
- Wastewater
- Residential Behavior

Although changes have been made, this Strategy is substantially based upon the recommendations offered by the Team (Appendix B). In addition, the strategies are based on solid environmental science, but since the requirements also affect a wide range of stakeholders within the Appoquinimink watershed, they also take into consideration and accommodate a variety of factors. These factors include but are not limited to location within the watershed; proximity to water resources; site specific physical characteristics; subdivision, project, and system size; future activities planned by other agencies/entities; and best available technologies. These Regulations also contemplate the issues associated with those living on fixed incomes, people with serious illness, people facing financial hardship, and owners of small parcels of land. Every attempt has been made to provide predictability and flexibility for all activities contributing point and nonpoint source pollution affected by these Regulations.

## AGRICULTURE

*The State should continue to responsibly fund nutrient management planning.*

COMMENTARY

To reduce agriculture's impact on water quality, Delaware legislated a nutrient management program in 2002 to oversee nutrient applications within the State. In 2003, 20% of farmers applying nutrients to 10 acres or more or those who manage 8 or more animal units within the state were required by the Nutrient Management Act to create and submit a nutrient management plan (NMP) to the Nutrient Management Commission (NMC). Each year between 2004 and 2007, another 20% of eligible farmers were required to have NMPs, with 100% implementation by January 1, 2007. These plans are routinely updated and modified to meet the nutrient needs of the future cropping rotations and practices.

The Delaware Nutrient Management Commission runs a NMP cost-share program. Based upon water quality data and the load reductions required by TMDLs, the Delaware Nutrient Management Commission has classified the Appoquinimink Watershed as a nutrient management critical area high priority. Thus, the farmers from this priority watershed have an added advantage to be considered a priority for the cost-share program if funds are available. Additionally, farmers who apply for Environmental Quality Incentive Program funds for best management practices will receive more points in the Natural Resource Conservation Service ranking process if they are located in a watershed with TMDLs.

AUTHORITY

The Delaware Nutrient Management Law places the authority to run the Nutrient Management Plan program with the Delaware Nutrient Management Commission.

NUTRIENT REDUCTION

Extensive research has been done to determine the nutrient reduction efficiency of nutrient management plans – 16% reduction in TN and 20% reduction in TP due to implementing nutrient management plans. For information on the detailed analysis used to determine these efficiencies and reductions, refer to Appendix D.

COST

The costs of implementing nutrient management plans has been estimated using data gathered by United States Department of Agriculture (USDA), Natural Resource and Conservation Service (NRCS) at the county and state level. Details about this cost calculation can be found in Appendix E. Cost estimates were based on the size of the farm and the Appoquinimink Watershed contains farms that are mostly less than 500 acres. The cost of creating a nutrient management plan for a 3-year plan in a farm this size is $5.70, if they become eligible for the cost share program of the Nutrient Management Act.

ACTION

The Department forwarded this recommendation to the Department of Agriculture along with a commitment to assist them with locating the funds necessary to run programs that encourage continued compliance with the Nutrient Management Law. The Team should work with the General Assembly to ensure that the DNMC and its programs are adequately funded.

## *The State should continue to responsibly fund agricultural best management practice installation to increase current levels of implementation.*

COMMENTARY

The farmers of the Appoquinimink Watershed along with assistance from the USDA-NRCS, New Castle Conservation District, Farm Service Agency, Nutrient Management Commission and Department of Agriculture have done an impressive job of implementing best management practices. Maintaining the implemented amounts of agricultural best management practices found in Table 5 is very important to continue reducing nutrients throughout the watershed. Part of the reason for such successful implementation is the continued funding of best management practices through cost share programs at the federal, state and county levels.

Table 5: Current Area of Implemented Agricultural BMPs

| | *Acres* |
|---|---|
| *Cover Crops* | 3,145 |
| *Ponds* | 3 |
| *Grassed Waterways* | 3 |
| *Grassed Filter Strips* | 20 |
| *Wildlife Habitat* | 1,414 |
| *Grassed Filter Strips* | 54 |
| *Forest Buffers* | 55 |
| *Riparian Buffers* | 5 |
| *Wetlands* | 2,461 |
| *Field Border (feet)* | 18,299 |
| *Critical Area Planting* | 36 |
| *Conservation tillage* | 4,182 |

AUTHORITY

The United States Congress and Delaware General Assembly authorize the amount of money available for cost share programs run through the USDA-NRCS, New Castle Conservation District, Farm Service Agency, Nutrient Management Commission, and Department of Agriculture. In addition, these entities are critical to provide the expertise necessary to use this funding to maintain and even increase BMP implementation in the Appoquinimink watershed.

NUTRIENT REDUCTION

The nutrient reduction ability varies across the suite of BMPs implemented in the Appoquinimink watershed as seen in Table 6.

Table 6: Nutrient Reductions of Current Agricultural BMPs

| | *TN efficiency* | *TP efficiency* | *TN reduced (lb/day)* | *TP reduced (lb/day)* |
|---|---|---|---|---|
| *Cover Crops* | 0.55 | 0.05 | 118.25 | 0.25 |
| *Ponds* | N/A | N/A | 0.11 | 0.00 |
| *Grassed Waterways* | N/A | N/A | 0.12 | 0.00 |
| *Grassed Filter Strips* | N/A | N/A | 0.82 | 0.01 |
| *Wildlife Habitat* | N/A | N/A | 58.10 | 0.77 |
| *Grassed Filter Strips* | 0.46 | 0.54 | 5.62 | 0.13 |
| *Forest Buffers* | 0.62 | 0.62 | 7.64 | 0.16 |
| *Riparian Buffers* | 0.62 | 0.62 | 0.67 | 0.01 |
| *Wetlands* | 0.62 | 0.62 | 343.91 | 7.38 |
| *Field Border (feet)* | 0.04 | 0.29 | 0.35 | 0.00 |
| *Critical Area Planting* | N/A | N/A | N/A | 0.00 |
| *Conservation tillage* | N/A | N/A | N/A | 0.01 |

COST

The costs of implementing BMPs have been estimated using data gathered by United States Department of Agriculture (USDA), Natural Resource and Conservation Service (NRCS) at the county and state level. Recently, changes in the state cost share program have required a Pollution Control Strategy for watershed residents to receive funding. Thus, the state cost share information found in Table 7 is based on a PCS approved for the Appoquinimink watershed. These are estimates, as costs for specific project may vary.

Table 7: Agricultural BMP Costs

| | *Installation Cost / Acre* | *Lifespan (years)* | *Total Maintenance Costs over Lifespan* | *Total Cost/ Acre* |
|---|---|---|---|---|
| *Cover Crops* | $49.33 | 1 | $5 | $54.33 |
| *Ponds* | $3,758.50 | 10 | $5 | $3,808.50 |
| *Grassed Waterways* | $16,404.24 | 10 | $5 | $16,454.24 |
| *Filter Strips/Wildlife Habitat* | $495.24 | 10 | $5 | $545.24 |
| *Forest Buffers* | $495.24 | 15 | $5 | $570.24 |
| *Riparian Buffers* | $502.00 | 15 | $5 | $577.00 |
| *Wetland Restoration* | $4,374.50 | 15 | $5 | $4,449.50 |

| | | | | |
|---|---|---|---|---|
| *Field Border* | $495.24 | 10 | $5 | $545.24 |
| *Critical Area Planting* | $7,229.24 | 10 | $5 | $7,279.24 |
| *Conservation Tillage* | $17.33 | 4 | $5 | $37.33 |

ACTION
The Department forwarded this recommendation to the Department of Agriculture along with a commitment to assist them with locating the funds necessary to run programs that encourage adoption and maintenance of best management practices in the Appoquinimink Watershed. The Team should work with the General Assembly to ensure that the DNMC and its programs are adequately funded.

## *The County and State should continue their efforts to preserve farmland in the Appoquinimink watershed.*

COMMENTARY
The Delaware Agricultural Lands Preservation Program was formed in July 1991, with the adoption of House Bill 200. It is the only official program that protects land for agricultural purposes. The program has two major components namely Agricultural Preservation Districts and Agricultural Conservation Easements. The landowner joins the program by creating an Agricultural Preservation District. The district contains at least 200 contiguous acres that are devoted to agricultural or related uses. Any lands less than 200 usable (and contiguous) acres within three miles of an established district can be enrolled in the program as a district expansion. A district is a voluntary agreement to use land only for agricultural purpose for at least a ten year period. The landowner does not receive monetary benefits for creating the district, however the landowner gets tax benefits, right-to-farm protection, and an opportunity to sell a preservation easement to the State that keeps the land free from development permanently.

As of July 2007, there were 145,243 acres in 684 Agricultural Preservation Districts and district expansions in Delaware (DOA, 2007). Of this, 18,311 acres of the total preserved lands are in New Castle County. Out of the 145,243 acres currently in agricultural preservation districts, 488 properties encompassing approximately 84,990 acres have been permanently protected through the purchase of preservation easements for 134.3 million dollars. In New Castle County 11,501 acres of farmland are permanently preserved. The agricultural easement breakdown by county is illustrated in Table 8.

Table 8: Breakdown of Agriculture Easement by County

| | *Number of Farms* | *Acres* | *Cost* |
|---|---|---|---|
| *Kent* | 242 | 46,453 | $59,416,916 |
| *New Castle* | 72 | 11,501 | $27,524,662 |
| *Sussex* | 174 | 27,036 | $47,339,056 |
| *Total* | 488 | 84,990 | $134,280,634 |

Source: DOA, 2007

In the Appoquinimink Watershed, around 1,463 acres of land is preserved in the Delaware Agriculture Preservation Program. Of the total preserved land, around 1,168 acres have been permanently protected through the purchase of preservation easements (DOA, personal communication, 2007).

On July 8, 2009, the Senate Bill No. 129 was passed which adopts the recommendation of the Irrigation Preservation Task Force created by House Concurrent Resolution No. 67 of the 144th General Assembly. The Bill permits farmers, including any agricultural preservation land, to accept reclaimed water through irrigation systems. This Bill may help to achieve further enrollment of agricultural land into preservation programs, as this action item recommends.

AUTHORITY

Delaware Agriculture Lands Preservation Foundation has the authority to protect farmland. There is no official program to protect farmland at local level and there are few land use controls at the local levels that effectively preserve or attempt to preserve agricultural land.

NUTRIENT REDUCTION

The Department is unable to associate nutrient load reductions with this recommendation although the water quality and stream benefits from preventing an increase in impervious surface coverage are recognized.

COST

This is a very expensive practice. On average, the Agriculture Land Preservation Foundation is currently paying $1,580 per acre. As of July 2007, the Foundation has spent around 134.3 million dollars to permanently preserve 84,990 acres. In New Castle County, the Foundation has spent 27.5 million dollars to preserve 11,501 acres of agricultural land. The amount of money spent to preserve agricultural land at the county level is shown in Table 8.

ACTION

The Department will work with the Department of Agriculture to further this recommendation.

## *Create a recognition program for farmers in the Appoquinimink watershed who do the most to protect water quality.*

COMMENTARY

In 2001, poultry integrators in cooperation with the Delaware Nutrient Management Commission established the Delaware Environmental Stewardship Award Program. The award recognizes farmers whose stewardship and general farm practices contribute to conservation of the environment, water quality, and farmland. This program is, however, focused to the poultry growers and recognizes those growers by evaluating their nutrient management, best management practices, farm management, biodiversity and wildlife management.

Although most farmers in the Appoquinimink watershed would not be eligible for this award, as they are not poultry producers, a similar and relevant program for the Appoquinimink Watershed can be started.

AUTHORITY

This is not an issue with this recommendation.

NUTRIENT REDUCTION

This program will benefit water quality through its promotion of nutrient reducing best management practices. Although the Department is unable to specifically attach nutrient reductions to the program, nutrient reductions can be estimated by tracking the BMPs that are utilized on all farms in the watershed.

COST

The cost would be minimal including the design and production of signs, a brochure on the program, and the winner's reward.

ACTION

The Department and the Team should work with partners such as the USDA-NRCS, Nutrient Management Commission, New Castle Conservation District and Farm Service Agency to implement this recommendation.

## DEVELOPMENT

*The State should promulgate minimum standards for nutrient reduction as they relate to development. The County and local governments should enact ordinances that will achieve those standards within one year of the promulgation of the PCS.*

COMMENTARY

The Watershed Assessment Section has developed the Nutrient Load Assessment Protocol. The Protocol is a tool used to assess the changes in nutrient loading as a result of changes in land use. It works on a parcel basis and serves as an indicator to state, county and local government agencies as to the impacts of proposed development on water quality. It provides potential ways to mitigate a project's negative impacts and encourages developers to incorporate better conservation practices in their development where water quality is poor.

The Nutrient Load Assessment Protocol should be used during the improvement or development of a parcel. This budget must show that future land use will reduce nutrient loading by the amount required by the TMDL, and if this is not possible, the budget must show that required nutrient reducing best management practices are incorporated. This result from the protocol should then be submitted to the Department to be included in the Preliminary Landuse Service (PLUS) review process and used as a backup for information for permit requirement.

Local governments present in the Appoquinimink watershed have already developed ordinances that will help to reduce nutrient loading related to development. The Town of Townsend has developed a comprehensive water resources environmental ordinance that protects wetlands, recognizes critical natural areas, promotes reforestation and preserves buffers. Similarly, the Town of Middletown with assistance from the Appoquinimink River Association has developed a riparian buffer protection ordinance to mitigate the impact of developed land on the waterways. The Town of Odessa has updated their zoning ordinance to include source water protection and riparian buffer protection which aids in nutrient removal.

New Castle County has also enacted environmentally protective ordinances. On July 8, 2003, New Castle County passed an ordinance entitled "Environment First" which addresses water quality by increasing the amount of stormwater runoff that is absorbed into the ground as well as increasing the open space preserved during the development process. "Environment First" was designed to enhance the protection of our environment and natural resources and not compete with it.

AUTHORITY

DNREC Watershed Assessment Section will be responsible for investigating the use of the nutrient budget protocol in the PLUS process as well as educating local governments and engineers about using the protocol.

NUTRIENT REDUCTION

Urban riparian buffers, low impact development incorporating green technology BMPs, and impervious cover limitations on developed land can be used as mechanisms to meet required nutrient reductions as they relate to development. The reduction of nutrient loading in developed land depends on the type of BMPs adopted. Nutrient reduction efficiencies of some of the widely used BMPs are summarized in Table 9. It is important to note that currently the DNREC Sediment and Stormwater Program is analyzing various stormwater BMP efficiencies and these efficiencies could slightly change in the future.

Table 9: Nutrient Reduction Efficiency of Best Management Practices

| | *Nitrogen Reduction Efficiency* | *Phosphorus Reduction Efficiency* |
|---|---|---|
| *Wet Pond* | 12 | 55 |
| *Dry ponds* | 15 | 25 |
| *Infiltration Practice* | 65 | 70 |
| *Filtering Practice* | 38 | 59 |
| *Open channel Practice* | 25 | 29 |

Source: Guide for Best Management Practice (BMP) Selection in Urban Developed Areas. 2001. American Society of Civil Engineers.

COST

Costs for this recommendation cannot be calculated.

ACTION

DNREC Watershed Assessment Section will investigate the use of the nutrient budget protocol in the PLUS process as well as assisting in the education of local governments and engineers in the use of the protocol.

## *State, county and local governments should coordinate efforts with nonprofit organizations to provide an ongoing environmental education and outreach program for residents.*

COMMENTARY

Nonpoint Education for Municipal Official (NEMO) is an education and outreach program that is specifically targeted at educating local landuse decision makers. Delaware NEMO is a statewide network of educators, resource managers, and planners working together to provide communities with educational programs and materials to help them plan where and how to develop while protecting their natural resources. NEMO promotes planning that considers a community's character, unique features and natural resources. The Delaware NEMO Program offers various free workshops which are open to anyone interested in better landuse design.

Similarly, the Appoquinimink River Association is actively involved in promoting, developing and engaging in educational activities related to southern New Castle County watersheds including the Appoquinimink Watershed. One project that the Association uses to educate the public is open space and riparian buffer reforestation demonstrations. The Association has used this program to help several watershed communities and residents with maintaining their community's open space, riparian buffers, and stormwater management areas. The Association, in collaboration with Delaware Nature Society, has offered the "Smartyard" landscaping package to the residents of watershed as well as a "Most Welcoming Yard" contest in Townsend, both to teach about the benefits of native landscapes. They also conducted a Stream Watch Program, which provided a basic level of training on biological indicators of a healthy stream and simple chemical test used to assess water quality. Their education and outreach continues at public events such as the Middletown Peach Festival, Townsend Day, Odessa Halloween in the Park and the Blackbird Creek Fall Festival where the Association provides large amounts of material to help local communities maintain their backyards and neighborhoods in an environmentally friendly way. The Association also provides a newsletter and presentations to homeowners associations, local governments, and civic organizations on a variety of environmental topics that can help communities maintain the environmental aspects of their lives.

AUTHORITY
Land use issues are under the authority of counties and local governments.

NUTRIENT REDUCTIONS
Although nutrient loading from development will likely be reduced by educating residents, the Department is currently unable to estimate this load reduction.

COST
Not available.

ACTION
The Department along with the Office of State Planning Coordination will work with local governments and nonprofit organizations to provide environmental education and outreach.

## *Stormwater*

*All permanent sediment and stormwater management plans should be designed and implemented to include criteria that will reduce nutrient loading by the percentage required to meet TMDL-required nutrient load reductions of ground and surface waters to the maximum extent practicable.*

COMMENTARY
The Delaware Sediment and Stormwater Regulations govern the plans and design criteria that are implemented in the State. Current regulations minimize water quality and quantity impacts due to land disturbing activities by preferring the use of "Green Technology BMPs". "Green Technology BMPs" are those practices that achieve stormwater management objectives by applying the principles of filtration, infiltration and storage most often associated with natural vegetation and undisturbed soils while minimizing a reliance on structural components. These BMPs have been shown to be effective in nutrient reduction.

Additionally, the report "Governor Minner's Task Force on Surface Water Management" recommends including nutrient reduction as an aspect of sediment and stormwater law. As part of recommendations 10 A and B, it is suggested that State Sediment and Stormwater regulations and plans be updated to include requirements for stormwater recharge, runoff volumes, land use cover conditions, turbidity limits, adequate conveyance and pollutant loads. The sediment and stormwater regulations are currently under revision and will be modified to better address volume management by increasing emphasis on recharge and infiltration of stormwater, where it is technically and environmentally feasible. In addition, regulations should include design criteria to reduce nutrient contributions through practices such as comparing post development conditions with and without stormwater quality controls, using treatment trains of stormwater controls, or reducing impervious cover.

AUTHORITY

The Division of Soil and Water Conservation is responsible for implementation of this requirement through the update of the Sediment and Stormwater Regulations.

NUTRIENT REDUCTION

The load reduction will be based upon the type of BMPs that have been adopted. The nutrient reduction efficiency of some of the most commonly used best management practices is depicted in Table 10.

Table 10: Qualitative Pollutant Removal Efficiencies

| Relative Pollutant Removal Capabilities for Storm Water Treatment Practices | | | | | | |
|---|---|---|---|---|---|---|
| | *TSS* | *TP* | *TN* | *Metals* | *Bacteria* | *Oil & Grease* |
| *Dry Detention Ponds* | ○ | ○ | ○ | ○ | ○ | ○ |
| *Wet Ponds* | ● | ● | ⦿ | ● | ● | ● |
| *Stormwater Wetlands* | ● | ● | ⦿ | ⦿ | ● | ● |
| *Filtering Practices* | ● | ● | ● | ● | ○ | ● |
| *Infiltration Practices* | ● | ● | ● | ● | ● | Don't Use |
| *Water Quality Swales* | ● | ⦿ | ● | ● | ○ | ⦿ |
| ● High Removal ⦿ Medium Removal ○ Low Removal | | | | | | |

Source: CWP, 2005

COST

The cost varies with type of BMPs that are adopted. An average cost of BMPs is provided in Table 11.

Table 11: Base Costs of Typical Applications of Stormwater BMPs[1]

| | *Typical Cost ($/BMP)*[1,2] | *Application* | *Data Source* |
|---|---|---|---|
| *Retention Basin* | $100,000 | 50-Acre Residential Site (Impervious Cover = 35%) | Adapted from Brown and Schueler (1997b) |
| *Wetland* | $125,000 | 50-Acre Commercial Site (Impervious Cover = 35%) | Adapted from Brown and Schueler (1997b) |
| *Infiltration Trench* | $45,000 | 5-Acre Commercial Site (Impervious Cover = 65%) | Adapted from SWRPC (1991) |

| | | | |
|---|---|---|---|
| *Infiltration Basin* | $15,000 | 5-Acre Commercial Site (Impervious Cover = 65%) | Adapted from SWRPC (1991) |
| *Filtering Practices* | $35,000-$70,000[3] | 5-Acre Commercial Site (Impervious Cover = 65%) | Adapted from Brown and Schueler (1997b) |
| *Bioretention* | $60,000 | 5-Acre Commercial Site (Impervious Cover = 65%) | Adapted from Brown and Schueler (1997b) |
| *Grass Swale* | $3,500 | 5-Acre Commercial Site (Impervious Cover =35%) | Adapted from SWRPC (1991) |
| *Filter Strip* | $0-$9,000[3] | 5-Acre Commercial Site (Impervious Cover = 35%) | Adapted from SWRPC (1991) |
| From EPA, 1999 –Urban Storm Water Best Management Practices Study<br>1 Base costs do not include land costs.<br>[2] Total capital costs can typically be determined by increasing these costs by approximately 30%.<br>[3] A range is given to account for design variations. | | | |

ACTION

With the promulgation of the new proposed Sediment and Stormwater Regulations by the end of 2010, the Department believes that this recommendation will be met. If the new regulations are not promulgated as anticipated, the Department will promulgate stormwater regulations for the Appoquinimink watershed that meet this recommendation and the required TMDL reduction.

*Local governments should establish a community stormwater runoff education and stormwater management area maintenance program for the watershed to provide resources to educate homeowners, homeowners' associations (HOAs), and groups that maintain stormwater structures.*

COMMENTARY

Maintenance of stormwater structures is imperative to ensure proper functioning. Resources are needed in order to have a fully functioning inspection program. During the times of tight budgets and hiring freezes, implementing a program of this magnitude will be difficult. However, education can be done with a relatively low level of funding. The Appoquinimink River Association (ARA) is doing an excellent job at establishing various outreach programs related to stormwater management. The Association gives presentations on the Appoquinimink Watershed and water pollution education to many local students, government officials, homeowner associations and civic groups. ARA has developed a document compiling information on all educational materials, activities, events and programs available to state residents on the topic of nonpoint source pollution. The ARA has also created educational materials and programs surrounding the topics of rain gardens and rain barrels. As part of their rain garden education program, they have created a large commercial demonstration rain garden at the Jean Birch MOT Senior Center in Middletown. This rain garden won an award from Region 3 EPA and the Low Impact Development Center for Leadership in Low Impact Development: Education and Outreach. Several workshops were held by the ARA for residents to learn backyard conservation including creating their own rain barrels for use at home to alleviate issues of stormwater runoff.

AUTHORITY

There are two programs that regulate stormwater in the Appoquinimink watershed. One is the National Pollution Discharge Elimination System (NPDES) permit program, through the Clean Water Act, which requires the County, the Department of Transportation, and the Town of Middletown to obtain permits for their stormwater program. This program is administered through the Division of Water Resources. One of the permit requirements includes public outreach. Thus, the permittees may be interested in working with the Department to implement this action. Another is the State's Sediment and Stormwater Program, administered through the Division of Soil and Water Conservation. This program is in the process of revising their regulations. These regulations address inspection and required maintenance on permitted structures through the respective delegated agency. The responsible inspection agency shall ensure preventive maintenance through inspection of all stormwater management practices and keep record of the inspection report. The inspection needs to be done at least once a year. Although the regulations do not specifically address education, the Department will take every opportunity to educate the regulated community. In addition, the Department will work with the Governor's office to find funds for increased inspection capabilities.

NUTRIENT REDUCTIONS

Although nutrient loading from development will likely be reduced when educating residents on stormwater runoff and stormwater management area maintenance, the Department is currently unable to estimate this load reduction. However, current stormwater best management practices have been implemented and the Department estimates that these practices have contributed to achieve 4.44% of the Total Nitrogen and 30.0% of Total Phosphorus load reduction needed to achieve the TMDL. For further information on the nutrient reductions refer to Appendix D.

COST

Not available.

ACTION

The Department will commit to provide guidelines, technical standards, and assistance, as requested from the local governments to set up an education and outreach program.

*Within 6 months from the promulgation of the PCS, DNREC should convene a group composed of representatives from the community and local, county, and state government to establish a stormwater retrofit process for the Appoquinimink watershed.*

COMMENTARY

This is an excellent, but resource intensive recommendation. This may be best implemented by having all parties collaboratively apply for federal grants to fund retrofit projects. The Appoquinimink Retrofit Assessment conducted by the CWP has identified three categories of retrofits (offsite storage, onsite nonresidential, and onsite residential) with the primary objective of increasing water quality treatment and recharge, and to mitigate localized flooding and channel erosion. The study has identified most of the retrofit opportunities in the Dove Nest Branch, Deep Creek, and Appoquinimink I sub-watersheds and have developed retrofit concepts for over 51 potential projects. The study further recommended installing at least three priority structural stormwater retrofits over the next few years. Since the Assessment was finished in 2005, the Appoquinimink River Association has helped to implement several priority projects as categorized by the CWP. The Association has completed a retrofit at the Jean Birch MOT Senior Center into a rain garden and is working on a retrofit on the Broad Street Drainage in Middletown. In addition, because of the Assessment, DelDOT has also been working on implementing several priority stormwater retrofits in the Appoquinimink Watershed including work at the Odessa Professional Park, Middletown Maintenance Yard, and Lakeside Drive and DE-71. The Town of Middletown has also retrofitted the old Acme site into their new Town Hall. The Appoquinimink School District also retrofitted Townsend Elementary School as part of their construction of the adjoining Townsend Early Childhood Center.

AUTHORITY

The Department has the authority to implement this recommendation. However, for greatest chance of success, all partners should work together to locate grant funds that could be used to implement projects where there is stakeholder interest.

NUTRIENT REDUCTION

The benefits from retrofit projects are very site specific and depend on the type of the treatment practice adopted and the pollution load reduction potential. The pollutant removal efficiencies of various treatment practices determine pollution load reduction potential. This reduction in nutrient load can be imperative when deciding which BMP is best for a retrofit project. The nutrient reduction from retrofit projects can range from 15% to the 85%.

COST

Retrofits are costly and vary dramatically. Stormwater retrofits can be one of the most expensive urban restoration practices to implement as retrofit projects require design, permitting, construction, and long-term maintenance costs. Storage retrofits require more total capital dollars to construct, but are cost effective in terms of cost per unit treated whereas onsite practice particularly onsite residential practices are less expensive, but treat smaller areas.

Since retrofits are very expensive, willing partners and interested stakeholders should be identified for technical and financial assistance. In addition, small-scale, well-planned, and visible demonstration projects should be implemented to garner support (financial and public approval) for future efforts.

ACTION

The Department will convene this group.

## *Encourage the creation of a stormwater utility pilot project in the Appoquinimink watershed.*

COMMENTARY

Governor Minner’s Task Force on Surface Water Management quantified the statewide financial need for stormwater management. “The Finance Subcommittee identified stormwater capital requirements of $207.3 million over the next five years and projected annual maintenance requirements of $13.73 million" (DNREC, 2005). The Task Force thus recommended that a stormwater utility operating at the county or local level should be formed as a funding vehicle for the purpose of providing a simplified and comprehensive approach to drainage and flooding problems. A stormwater utility is an approach that can generate a stable source of funding for stormwater management within the region. The funds are made available by collecting user fees. Stormwater utility fees are generally set by the amount of impervious cover on each resident's property. The higher the impervious cover the higher the fee. GIS mapping will be utilized to measure impervious surface generated by residential and commercial development, and the utility fee will be charged based on the property's Equivalent Runoff Unit (ERU).

The Sediment and Stormwater regulations serve as an enabling structure for the local ordinances needed in order to set up the utility. For example, the City of Wilmington has established a stormwater utility for residential and commercial customers in the municipality where all properties pay a stormwater charge based on their impervious cover.

AUTHORITY
The Division of Soil and Water and associated County and local governments has the authority for the implementation of this recommendation.

NUTRIENT REDUCTION
The nutrient reductions depend on the projects implemented from the fees.

COST
The City of Wilmington has spent approximately $400,000 to establish a stormwater utility. The cost estimate includes: technical work, establishing a defensible rate system and public outreach (Source: City of Wilmington, Personal communication, 2007).

ACTION
The Department will assist New Castle County and local governments in developing a stormwater utility program.

## *Impervious cover limits*

*The State should promulgate a watershed-wide limit for impervious coverage with consideration for site-specific mitigation and emphasis on water resource protection areas.*

COMMENTARY
In 1992, watershed impervious cover was estimated to be 4% which grew to 9% in 2007 and is expected to reach 25% in the future (CWP, 2005). Recent research has revealed a strong relationship between impervious cover and various indicators of stream quality. When porous land cover is converted to impervious cover, a greater fraction of annual rainfall is converted to surface runoff, and a smaller volume recharges the groundwater. This increased surface runoff

volume causes higher peak flows that erode stream channels and lower baseflow, which ultimately results in in-stream habitat degradation. In addition, surface runoff carries a suite of pollutants that can degrade water quality.

Stream research generally indicates that at about 10% impervious cover, sensitive stream elements are lost from the system. A second threshold appears to exist at around 25-30% impervious cover, where most indicators of stream quality consistently shift to a poor condition. The Center for Watershed Protection has developed the following stream classification (Table 12) based on the relationship between impervious cover and stream health.

Table 12: Impervious Cover Classification

| *Classification* | *Description* |
|---|---|
| Sensitive (≤10% IC) | • Typically high quality streams (though rurally-impacted watersheds will have low impervious cover)<br>• Generally have stable channels, excellent habitat structure, good to excellent water quality, diverse communities of both fish and aquatic insects<br>• Do not see frequent flooding and other hydrological changes associated with urbanization |
| Impacted (11%-25% IC) | • Show clear signs of degradation due to watershed urbanization<br>• Greater storm flows begin to alter the stream geometry<br>• Both erosion and channel widening are clearly evident<br>• Stream banks become unstable, and physical habitat in the stream declines noticeably<br>• Stream water quality shifts into the fair/good category during storms and dry weather<br>• Stream biodiversity declines to fair levels, fewer sensitive fish and aquatic insects |
| Non-supporting (11%-25% IC) | • Streams essentially conduits for conveying stormwater flows<br>• Stream channel becomes highly unstable, and many reaches experience severe widening, down-cutting and streambank erosion<br>• Pool and riffle structure diminished or eliminated, and the stream substrate can no longer provide habitat for aquatic insects, or spawning areas for fish<br>• Water quality often rated fair to poor, and water contact recreation not possible<br>• Subwatersheds generally display increases in nutrient loads to downstream receiving waters, even if effective urban stormwater treatment practices are installed and maintained.<br>• Biological quality is generally considered poor, dominated by pollution tolerant species |

Source: CWP, 2005

Land use estimates from 2002 show that three subwatersheds of the Appoquinimink Watershed are classified as sensitive, three as impacted, and one as borderline sensitive/impacted (CWP, 2005). Future growth estimates project that except the Appoquinimink II subwatershed, all other all subwatersheds will shift to the impacted or non-supporting categories.

Water Resource Protection Areas (WRPAs) are defined as (1) surface water areas such as floodplains, limestone aquifers and reservoir watersheds, (2) wellhead areas, or (3) excellent recharge areas. Since 1991, WRPA ordinances have been a part of source water protection in New Castle County, Delaware. Source water is any aquifer or surface water body from which water is taken either periodically or continuously by a public water system for drinking or food processing purposes. The ordinance limits the amount of impervious cover to 20% by right for new development in mapped recharge and wellhead areas. The purpose of impervious cover thresholds in WRPAs is to balance the need to protect drinking water sources with the right to economically develop land, minimize loss of recharge, and protect the quality and quantity or ground and surface water supplies.

In the Source Water Protection Guidance Manual for the Local Governments of Delaware, local governments are encouraged to adopt ordinances that protect ground and surface waters in WRPAs through a source water protection hierarchy (ranked in descending order of preference):

1. Preserve WRPAs as open space and parks by acquisition or conservation easement.
2. Limit impervious cover of new development to 20% within WRPAs.
3. Allow impervious cover of new development to exceed 20% within WRPAs (but no more than 50% impervious) provided the applicant develops recharge facilities that directly infiltrate rooftop runoff.
4. Allow impervious cover of new development to exceed 20% within WRPAs (but no more than 50% impervious) provided the applicant develops recharge facilities that infiltrate stormwater runoff from forested and/or grassed surfaces with pretreatment.

With the potential for future growth to affect the water quality of the rivers, streams, and ponds of the Appoquinimink Watershed, regulations need to include impervious cover limits for new subdivisions and major land disturbing activities. Regulations need to prevent impervious cover levels over 50% and for impervious cover levels over 20%, there needs to be an environmental impact assessment report and mitigation to ensure water quality protection.

The new State Sediment and Stormwater Regulations are expected to limit some of the negative effects of impervious cover by virtue of the requirement that stormwater must be infiltrated rather discharged through a conveyance system. If infiltration is not possible on the site, the stormwater treatment on site must have several best management practices designed to reduce the stormwater nutrient and bacteria load. As for existing property that will be redeveloped, unless new construction will be undertaken on the property, no reduction of impervious cover will result. The exact nature that impervious cover will be dealt with through the revised regulations will be unveiled in the spring of 2010.

The Department recommends that the effective impervious cover be reduced on redeveloped properties. Effective impervious cover is the portion of the total amount impervious cover that is directly connected to the storm drain system. Impervious cover that drains to vegetated areas where stormwater can infiltrate, or be filtered and stored, is not considered part of the effective impervious cover.

Current regulations exist in the watershed to protect impervious cover in source water protection areas. The New Castle County UDC limits the impervious cover of new developments within WRPAs to 20% by right or up to 50% provided the applicant prepares a climatic water budget to balance predevelopment and post development recharge and installs facilities to augment recharge. The Unified Development Code (UDC) also protects floodplains, floodways, wetlands, riparian buffers, water recharge areas, moderate steep slopes and critical natural area by limiting percentage of impervious cover in the area.

The Town of Townsend has also developed Environmental Protection Regulations, which includes a section that clarifies environmental constraints and requirements for development in environmentally sensitive areas. This section includes regulations for development and delineation of water resource protection areas including wellhead Class A and recharge areas.

The Townsend WRPA ordinance permits new development within recharge WRPAs provided the impervious cover does not exceed 30% for residential uses in the outlying greenbelt and 50% for new development in the downtown district. Middletown's land area is classified as having excellent recharge capacity. The Town of Middletown recently passed a source water protection ordinance that does not contain impervious cover limits in WRPAs but does require secondary containment of above and underground storage tanks, requires the volume and quality of recharge in recharge areas to be equal to predevelopment levels, and protects the area 300 feet around public water supply wells. The Town of Odessa also has WRPA regulations that limit impervious cover. As a part of these regulations, there is no new development allowed in floodplains WRPAs, areas confirmed as recharge WRPAs are required to have 25% remain in open space with no impervious cover, and wellhead WRPAs have limits on impervious cover.

AUTHORITY

The State of Delaware Source Water Protection Law of 2001 requires local governments with year-round populations of 2,000 or greater to implement measures to protect the quality and quantity of public water supplies within delineated surface water, wellhead and groundwater recharge areas by 2007. This law requires New Castle County and Middletown to develop measures while Odessa and Townsend are not required. Also, the Division of Soil and Water Conservation is responsible for implementation of this requirement through the inclusion of impervious cover limits in the update of the Sediment and Stormwater Regulations.

NUTRIENT REDUCTION

By limiting impervious cover as lands are developed, the impacts on water quality will be reduced. A specific numeric reduction is not currently available.

COST

This recommendation would only apply for new proposed development so it is not possible to calculate implementation costs at this time.

ACTION

With the promulgation of the new proposed Sediment and Stormwater Regulations by the end of 2010, the Department believes that this recommendation to establish watershed-wide limit for impervious coverage will be met. The Department will work with New Castle County or any municipality to develop effective impervious cover reduction controls through ordinances on redeveloped properties.

## *Government entities should provide developers suggestions and incentives for use of alternative pervious materials and strategies (to take the place of traditional impervious ones) for sidewalks and parking lots.*

COMMENTARY

It is widely accepted that as impervious coverage increases in a watershed, water quality decreases. Limiting impervious cover reduces the amount of runoff that can enter water bodies because more rainfall can soak into the ground. Research has consistently shown that once a threshold of imperviousness is crossed in a given watershed, water quality and/or stream habitat cannot be maintained at the predevelopment level. The consensus among many independent researchers is that watershed imperviousness should not exceed 10% in environmentally sensitive watersheds.

As research has uncovered the link between increased impervious cover and deteriorating water quality, businesses have developed porous paving products that can replace the impervious ones. Porous pavement is pavement that supports some vehicular traffic but can also allow significant amounts of water to pass through and recharge back into the ground. As seen in Table 13, porous pavement has many benefits, some of which other stormwater BMPs do not.

Table 13: Benefits of On-site Stormwater BMPs

| *Stormwater Reduction Practice* | *Delays Runoff* | *Reduces Runoff Volume* | *Peak Discharge Effect In Large Storms* |
|---|---|---|---|
| Rain Barrels | Yes | Yes | No |
| Cisterns | Yes | Yes | Yes |
| Rain Gardens | Yes | Yes | No |
| French Drains/ Dry Wells | Yes | Yes | No |
| Green Roofs | Yes | Yes | Maybe |
| Bioretention | Yes | Yes | Maybe |
| Filtering Practices | Yes | Maybe | Maybe |
| Storm Water Planter | Yes | Yes | No |
| Porous Pavement | Yes | Yes | Yes |

Based on 1997 land use figures, 5% of the land in the Appoquinimink watershed was estimated to be impervious. However, 2007 landuse data shows that 9% of the watershed is in impervious cover. The data also shows that the amount of land in residential or urban land use has almost doubled. This trend continues as the amount of impervious cover in the watershed is continually increasing with the conversion of land to residential or urban land uses. Estimates from the CWP Appoquinimink Implementation Plan project a watershed imperviousness level of 25% in the future based on a build out analysis using current zoning.

AUTHORITY

The Department may be able to promote the use of permeable material in the Sediment and Stormwater regulations as well as continuing to work with local governments to incorporate it in future development designs.

NUTRIENT REDUCTION

By limiting impervious cover as lands are developed, the impacts on water quality will be reduced. A specific numeric reduction is not currently available.

COST

Estimated costs for pervious pavement can be between $2-$10 per square foot.

ACTION
The Department will work with local governments to promote the use of porous pavement and include its use in land use ordinances where applicable.

## *Conservation design*

*State, county, and local governmental bodies should better define the concept of "conservation design" and enact codes and regulations that allow for and promote "conservation design" principles with the goal of reducing nutrient loads.*

COMMENTARY
Livable Delaware is a positive, proactive strategy that seeks to curb sprawl and direct growth to areas where state, county and local governments are most prepared for it in terms of infrastructure investment and thoughtful planning. It builds on the foundation laid by the Strategies for State Planning and Spending, first approved in 1999 and comprehensively updated in 2004. Under Governor Minner's administration, she unveiled the Livable Delaware Agenda in March 2001 and used it to coordinate state agency planning, resource management, and investments in order to support growth where it is appropriate and planned for, and discourage growth in inappropriate locations. Since its launch, almost every municipality throughout the state has taken steps to develop or update its comprehensive plan as towns must plan before they seek annexation. In addition, the State's Land Use Panning Act was overhauled so the State could provide more meaningful review and comment to a project at the initial process rather than at the end. Two documents have been released, and are designed to provide guidance and inspiration to local officials, citizen leaders, and developers as they consider development proposal throughout Delaware. Livable Neighborhoods Guide provides the guidance on the creation of Livable Delaware at the most local levels - household, backyard and neighborhood. Although the document does not specifically address "conservation design" it does define "community design" and incorporates elements of "community design" within the document. Better Models for Development in Delaware helps to create, maintain and enhance livable communities in Delaware.

Also, the Governor's Surface Water Management Task Force has recommended that conservation design be implemented as a way to reduce reliance on structural stormwater management practices. They define conservation design as a design that encourages the preservation of open space and natural areas while enhancing the market value of land development. Further recommendations for conservation design include the modification of local land use and zoning ordinances for its inclusion, and review of standards, specifications, and guidelines for coordination and consistency with the implementation of conservation design. Following on the footsteps of State Government, New Castle County initiated work on a conservation design ordinance and included multiple opportunities for citizen input in their efforts to enact a conservation design ordinance. On July 8, 2003, New Castle County passed an ordinance entitled "Environment First" that addresses conservation design and open spaces.

Local governments present in the Appoquinimink watershed have already developed ordinances that will help to reduce nutrient loading related to development. The Town of Townsend has developed a comprehensive water resources environmental ordinance that protects water resources through open space and natural resource protection as well as regulations that promote infiltration. Similarly, the Town of Middletown has a riparian buffer protection ordinance, codes that preserve open spaces and provide source water protection. The Town of Odessa has updated their zoning ordinance to include source water protection, innovative stormwater management, riparian buffer protection and erosion and sediment control.

New Castle County has also enacted environmentally protective ordinances including the "Environment First" which addresses water quality by increasing the amount of stormwater runoff that is absorbed into the ground as well as increasing the open space preserved during the development process. "Environment First" was designed to enhance the protection of our environment and natural resources and not compete with it.

One way to establish or develop environmental ordinances is by updating municipal comprehensive plans every five year such that new issues and/or concerns can be addressed. Delaware has 57 incorporated municipalities, all of which are required to keep their comprehensive plans up to date under Delaware State Law (22 Delaware Code, § 702). At least every 5 years a municipality is required to review its adopted comprehensive plan to determine if its provisions are still relevant given changing conditions in the municipality or in the surrounding areas. The adopted comprehensive plan are revised, updated and amended as necessary, and re-adopted at least every 10 years.

AUTHORITY
The County and local governments have the authority to enact further ordinances to increase environmental protection.

NUTRIENT REDUCTION
Although nutrient loading from development will likely be reduced when using conservation design versus traditional design, the Department is currently unable to estimate this load reduction. Conservation design leads to reduced impervious surface coverage. Increasing impervious cover is linked to deteriorating water quality.

COST
Specific costs are not available, although literature suggests that the costs of conservation design are less than conventional design.

ACTION
The Department can work with the Office of State Planning Coordination to convene the local governments to discuss updating their ordinances. This could be coordinated with the Office of State Planning Coordination.

## *Open Space*

*All open space land uses should be designed and managed for water quality protection, including reduced nutrient loading. Reforestation, meadow development, wetlands construction, and other natural resource preservation should be encouraged through increased outreach efforts by the appropriate jurisdictions and local nonprofit organizations.*

COMMENTARY

Open space can have many valuable functions. In impaired watersheds, water quality protection should be a priority for developers when designing open spaces. Maintenance of these spaces is important not only for the people living in these communities but for their water quality benefits. To educate this importance, DNREC's Delaware Coastal Program recently developed a document entitled "Community Spaces, Natural Places" which provides communities with information on practical and successful open space management techniques.

In addition, the Appoquinimink River Association has been very active protecting open spaces through various projects and outreach programs. They worked with DNREC Coastal Programs to develop a reforestation plan for the Cantwell Ridge and Odessa Chase communities and planted over 4,000 small trees and 125 large trees in the two communities, reforesting 10.8 acres. They have also received grants for the implementation of pet waste collection stations with biodegradable bags, distributed to various homeowner associations for use in open spaces.

New Castle County's "Environmental First" ordinance addresses some of these concerns to all new development proposals. The ordinance aims at preserving fifty percent of total acreage in open space for developments of 50 or more acres in the suburban district. While Odessa currently does not contain subdivisions that would have required open space creation, future development is planned and open space is required to be a minimum of 12.5% of the area. Also, the intent of Odessa's open land classification is to preserve and protect the natural areas in the Town of Odessa, to provide refuge for wildlife, protection for scenic vistas, and preserve the natural elements of the town's history. The Town of Townsend has requirements that all residential development containing 10 or more dwellings must have a minimum of 10% open space in the development. The Town of Middletown also has regulations that govern the open space of subdivisions. Depending on the density of the proposed subdivision, the percent open space required could be anywhere from 10 - 33% and conservation of natural vegetation is required to be conserved in its natural state.

AUTHORITY

Local governments oversee land use issues and as such, the Department will work with them to develop nutrient management plans for their open spaces. Additionally, the Department will work with the Nutrient Management Commission on including the prohibition of the application of nutrients to open space unless prescribed by a nutrient management plan.

NUTRIENT REDUCTION

Proper management of open space can help reduce the amount of nutrients entering waterways. Treating the creation of open space as a land use change from agricultural cropland to grassed open space, nutrient reductions can be calculated as seen in Table 14. For further explanation of the nutrient reduction calculation, refer to Appendix D.

Table 14: Nutrient Reductions due to Open Space Required in Developments

| | *Acreage* | *TN Reduction (lb/day)* | *TP Reduction (lb/day)* |
|---|---|---|---|
| *New Castle County* | 665.00 acres | 27.33 | 0.36 |
| *Town of Middletown* | 489.02 acres | 20.10 | 0.27 |
| *Town of Townsend* | 102.65 acres | 4.22 | 0.06 |

The nutrient reductions can be further reduced by prohibiting the nutrient applications to open space unless prescribed by a nutrient management plan.

COST

The cost is entirely dependent on the type of project or outreach program that will be established to manage open space. For instance, reforestation protection will cost more than pollution prevention pet waste project. Costs have been calculated for the creation of grassed open spaces at $400/acre.

ACTION

The Department will work with the Nutrient Management Commission, County and local governments to implement. The Department also requests communities to follow the guide developed by the Department's Coastal Program to restore, manage and maintain open space.

*Incentive efforts to better manage residential open spaces should be better publicized to residents and maintenance corporations in order to support enhancement of the open spaces.*

COMMENTARY

Creative use of current funding sources to promote more "natural" open space protection should be pursued. The New Castle Conservation District currently provides a 50% cost share program for communities to reforest their open spaces and the USDA-NRCS can provide cost share funding if the open space parcel is large enough to get a farm and tract number. In addition, The Delaware Department of Agriculture has developed various brochures and booklets that provide information on the effective ways of fertilizer application, irrigation and lawn management that can also be used in this type of outreach to educate homeowners associations on things they can do in their communities to help protect our waterways.

AUTHORITY

Authority is not an issue in implementing this recommendation although multiple partnerships involved in its execution would likely be most productive.

NUTRIENT REDUCTION

Nutrients entering ground and surface waters will be reduce as more best management practices on open space are implemented.

COST

The cost includes the staff time necessary and the cost associated to create an outreach program.

ACTION

The Department will provide support to partners when needed.

## **WASTEWATER**

*Seepage pits and cesspools should be prohibited within the watershed.*

COMMENTARY
Cesspools and seepage pits directly discharge wastewater into ground waters. Currently, there is no information about existing cesspools and seepage pits with the Appoquinimink Watershed.

AUTHORITY
The Department's Groundwater Discharges Section in the Division of Water Resources has the authority to implement this recommendation through the revision of the regulations governing the design, installation and operation of onsite wastewater treatment and disposal systems.

NUTRIENT REDUCTION
Due to lack of data on seepage pits and cesspools, there is no way to predict whether there will be a reduction.

COST
The cost depends on the number of systems that need replacement and the types of systems that would be permitted in their place.

ACTION
With the promulgation of the new proposed regulations governing the design, installation, and operation of on-site wastewater treatment and disposal systems regulations by the end of 2010, the Department believes that this recommendation for prohibition of cesspool and seepage pits will be met. If the new on-site wastewater treatment and disposal systems regulations are not promulgated as anticipated, the Department will promulgate the necessary regulations for this recommendation.

*Existing holding tanks must be operated in accordance with their permits and their conditions. In instances where central sewer service will become available within five years, temporary holding tanks will only be permitted after the Department receives a letter (with an approved Certificate of Public Convenience and Necessity (CPCN), where applicable) stating when central sewer will become available from New Castle County, the appropriate local government, or the wastewater utility.*

COMMENTARY
According to current data, there is one holding tank in the Appoquinimink watershed.

AUTHORITY

The Department's Groundwater Discharges Section in the Division of Water Resources has the authority to implement this recommendation through the revision of the regulations governing the design, installation and operation of on-site wastewater treatment and disposal systems.

NUTRIENT REDUCTION

Proper operation of this holding would require it be pumped out approximately once a month, which can reduce 33 lb/yr of nitrogen and 12 lb/yr of phosphorus reaching the waterways.

COST

The cost of pumping out a holding tank averages around $250 per system per pump-out. Since it is pumped out 12 times in the year, annual pump-out equates to $3000 per system. In addition to this cost, there is an annual inspection cost of $60 per system. Thus, the total expenditure for holding tanks is $3,060 per system per year.

ACTION

With the promulgation of the new proposed regulations governing the design, installation, and operation of on-site wastewater treatment and disposal systems regulations by the end of 2010, the Department believes that this recommendation for holding tanks will be met. If the new on-site wastewater treatment and disposal systems regulations are not promulgated as anticipated, the Department will promulgate the necessary regulations for this recommendation.

## *No new drainfields may be present within 100 feet of perennial and intermittent streams, lakes, and wetlands.*

COMMENTARY

Wastewater is disposed of through drainfields. A portion of the nutrients within the wastewater are adsorbed in the drainfield soils, however some nutrients, especially nitrogen, still leaches into groundwaters. By distancing the placement of drainfields from surface waters, this creates more opportunities for the nutrients from the wastewater to adsorb onto soils between the drainfield and water features, thereby reducing the amount that enters the waters.

AUTHORITY

The Department's Groundwater Discharges Section in the Division of Water Resources has the authority to implement this recommendation through the revision of the regulations governing the design, installation and operation of on-site wastewater treatment and disposal systems.

NUTRIENT REDUCTION

This requirement will reduce the additional nutrient loading from these new developments over what it would be if drainfield placement is allowed closer to the protected water features.

COST

The developers or homebuilders will absorb the costs of these systems.

ACTION
With the promulgation of the new proposed regulations governing the design, installation, and operation of on-site wastewater treatment and disposal systems regulations by the end of 2010, the Department believes that this recommendation on drainfield placement will be met. If the new on-site wastewater treatment and disposal systems regulations are not promulgated as anticipated, the Department will promulgate the necessary regulations for this recommendation.

## *Inspection/replacement*

*All properties utilizing an OWTDS that are sold or otherwise transferred to other ownership shall have their systems pumped out and inspected prior to the completion of the sale. These requirements can be filled by supplying (1) the certificate of completion, (2) documentation of a pump out and inspection within the previous 36 months, or (3) proof of a licensed operator or an annual service contract with a certified service provider.*

COMMENTARY
A septic compliance program will assist in protecting water quality by ensuring that systems are properly functioning which limits the amount of nutrients reaching ground waters. Section 8:0000 of the State's "Regulation Governing the Design, Installation and Operation of On-site Wastewater Disposal and Treatment System (OWTDS)" states that owners are responsible for maintenance and operation of OWTDS.

Since 1985, permits for onsite wastewater disposal systems have required that they be pumped out every 3 years as governed by the regulations. The New Castle County Unified Development Code (UDC) requires that septic systems be inspected and maintained in accordance with the State's regulations.

Many people already pay for inspections prior to purchasing a home and this is sometimes required by lenders. The Ground Water Discharge Section maintains a list of all the permitted haulers and licensed inspectors and this information is available for review on the Department's website. Additionally, the Department has developed various educational brochures related to septic system maintenance.

AUTHORITY
The Department's Groundwater Discharges Section in the Division of Water Resources has the authority to implement this recommendation through the revision of the regulations governing the design, installation and operation of on-site wastewater treatment and disposal systems.

Additionally, the Department has authority to regulate OSWDS. On July 11, 2003 the Governor signed House Bill 150 into law, which authorizes the Department to establish a license for persons who inspect systems and other OWTDS, and sets an annual license fee for septic system designers, installers, site evaluators, liquid waste haulers, inspectors and percolation testers, similar to other license fees charged by the Department. On January 1, 2006, DNREC developed and implemented Class H license for a septic system inspector.

NUTRIENT REDUCTIONS

There are currently around 1,436 onsite wastewater disposal systems permitted in the Appoquinimink watershed. Each day, these onsite treatment systems discharge around 75 pounds of nitrogen and 5 pounds of phosphorus to the groundwater of the Appoquinimink Watershed, assuming the systems are functioning properly (DNREC, 2009). After speaking with wastewater plant managers that accept septage from the watershed, it was estimated that around 100 tanks were pumped out during 2001. (The equivalent of septage from 53 tanks was taken to Wilmington. Kent County's WWTP also received some, but could not estimate a quantity. We are assuming less than 50, for a total of 100 tanks pumped). Using this information, a pump-out compliance rate was calculated at 12% in the Appoquinimink Watershed. Using this pump-out compliance rate, 156 lb/yr of nitrogen and 62 lb/yr of phosphorus is removed from the existing septic system nutrient load. This regulations will likely lead to an increase in the compliance rate and hence and increased nutrient load reduction, however the Department cannot currently quantify a specific value.

COST

The costs of the inspection will be covered through an agreement between the buyer and the seller. The cost of pumping-out OWTDS ranges from $185-200 per system, with an average cost of $192.50 per system (DNREC Small Systems Branch, personal communication, 2007). Permit conditions require that septic systems be pumped once every three years, which capitalizes this figure to $68.60/system/year. The proposed inspection will be performed at an estimated cost that range form $200 to $400 with an average cost of $300 at the time of pump-out (DNREC Small Systems Branch, personal communication, 2007). Thus, the inspection fee will only be incurred once every three years, so that annually it equates to $100. The total cost of the OWTDS inspection and compliance program will cost the system owner $169/system/year.

ACTION

With the promulgation of the new proposed regulations governing the design, installation, and operation of on-site wastewater treatment and disposal systems regulations by the end of 2010, the Department believes that this recommendation on drainfield placement will be met. If the new on-site wastewater treatment and disposal systems regulations are not promulgated as anticipated, the Department will promulgate the necessary regulations for this recommendation.

## *Convert as many lots as feasible (of less than 2 acres each) currently on septic to sewer connection in an equitable manner whereby those systems of high priority and feasibility (where there is already infrastructure in place) are converted first. The State and DNREC*

*should provide cost share and grant monies to these homeowners to help offset costs.*

COMMENTARY

The Town of Middletown currently provides sewer services to approximately 4,900 residential customers and 550 commercial and industrial customers. The town's wastewater is treated at the town's new spray facility, the Frog Hollow spray facility, and the New Castle County Water Farm I (Middletown Comprehensive Plan, 2005). The Town of Odessa uses the New Castle County owned sewer system and disposal facility at Water Farm I. The facility receives untreated effluent and treats it in a series of storage lagoons and finally either sprays onto farm fields for hay crops or discharge to the Appoquinimink River. The 1990 census reported that 102 of the 146 housing units in Odessa are connected to the sanitary sewer. Additional units were connected during 1990s; however updated census information on the topic is not available (Odessa Comprehensive Plan, 2006). Recently, an agreement has been made between Town of Townsend and New Castle County to provide sewer services and a sewer easement along Wiggins Mill Pond Road. The sewer agreement covers all the existing town and businesses in addition to 800 new homes and 45,000 square feet of commercial development (Townsend Comprehensive Plan, 2003).

Although local governments within the watershed have access to sewer facilities, there are still several subdivisions present in the watershed that utilize on-site septic systems. According to GIS analysis of 2002 landuse, around 72% of septic systems are found to be located on parcels less than 2 acres. This means that around 1,034 septic systems could be connected to the sewer connection, as this action item recommends.

Currently, DNREC's Septic Rehabilitation Loan Program provides a source of low interest financing for repairing or replacing failing septic systems or cesspools with on-site wastewater disposal systems that will function in an environmentally sound and cost effective manner.

This program is managed by the Financial Assistance Branch with technical assistance from the Groundwater Discharges Branch. Eligibility is open to property owners with on-site wastewater disposal systems that need rehabilitation in order to meet regulatory requirements, if they meet program income guidelines and the applicant demonstrates the ability to repay the loan. Financing is available at an interest rate of 3% or 6% depending on income, can be repaid over 20 years with no prepayment penalty. Loans are available for a minimum of $1,000 and a maximum of $15,000 for individual systems, and a maximum loan of $250,000 for community or mobile home park systems.

AUTHORITY

County and local governments have the authority to implement this recommendation.

NUTRIENT REDUCTION

Since, spray irrigation is more common in Appoquinimink watershed, we have assumed that all the treated effluent will used for spray irrigation. If 402 septic systems located on parcels of less than 2 acres are connected to sewer systems that use spray irrigation, the nutrient reduction from this conversion would be 6,918 pounds per year (18.95 lb/day) for total nitrogen and 496.06 pounds per year (1.36 lb/day) for total phosphorus.

COST

The average cost of constructing a sewer system is $8,500 per equivalent dwelling unit (EDU). In the future, the cost is expected to rise and reach $10,000/EDU (DNREC's Financial Assistance Branch, personal communication, 2007). The cost of financing these systems at an average 2% rate is currently $1,867/EDU and will be $2,194/EDU for future septic eliminations and sewer connection. Additionally system owners need to pay final septic system pump-out, crushing and filling the tank, and connection cost associated with building lateral line running from building to the right of way. These three expenditures equates to approximately $1000/EDU. All these cost are summed together and annual cost for 20 year period is calculated. Besides this, around $200 will be spent for operation and maintenance (O&M) costs including repair fees.

ACTION

County and local governments need to establish ordinances that encourage the conversion of septic systems to sewer districts. The Department can assist with implementing this recommendation.

## *Performance Standards*

*All new and replacement onsite wastewater disposal systems must be designed to achieve performance standards as specified in the updated State Regulations Governing the Design, Installation, and Operation of On-site Wastewater Treatment Systems . To provide proper operation and maintenance of the innovative and alternative onsite wastewater treatment and disposal system, the permittee is required to adhere to Department permit conditions. These permit conditions require mandatory operation and maintenance for the life of the system by maintaining a service contract with a certified service provider.*

COMMENTARY

While a portion of watershed is sewered, there are areas in the Appoquinimink Watershed that rely on onsite wastewater treatment and disposal systems for sewage disposal. The unsewered area of the Appoquinimink watershed falls outside of denoted urban boundaries. The County and local governments are doing their best to connect every possible subdivision with the sewer line, however due to remoteness of location, it may not be feasible. There are many subdivisions that rely on on-site septic systems as their wastewater management practice.

The Ground Water Discharges Section and the Watershed Assessment Section contracted with an expert in North Carolina to develop and recommend performance standards for all sizes of onsite systems. The permit applicant can select an approve technology from a list maintained by the Ground Water Discharges Section. Since alternative systems are more expensive than standard systems, the Department wants to ensure that they are functioning in order to ensure the nutrient reductions and protect the investment, and therefore will require a service contract with a certified service provider. The Inland Bays Pollution Control Strategy has already successfully implemented performance standards in southern Delaware.

AUTHORITY

The Department's Groundwater Discharges Section in the Division of Water Resources has the authority to implement this recommendation through the revision of the regulations governing the design, installation and operation of on-site wastewater treatment and disposal systems.

NUTRIENT REDUCTIONS

Technologies are available to reduce the nutrients in OWTDS effluent and are defined by the following performance standards: Performance Standard Nitrogen level 1 (PSN1) to achieve 5 mg/l at the end-of-pipe of the pretreatment unit; PSN2 10 mg/l at the end-of-pipe of the pretreatment unit; PSN3 20 mg/l at the end-of-pipe of the pretreatment unit; PSP1 4 mg/l at the end-of-pipe of the pretreatment unit; PSP2 8 mg/l at the end-of-pipe of the pretreatment unit.

There are currently no large systems greater than 2,500 gpd within the watershed. As existing systems less than 2,500 gpd fail and require replacement, PSN3 will be required and will result in a reduction of 9,884 pounds of nitrogen per year. All new systems that are required to use enhanced-nutrient removing technologies will actually add nutrients to the system.

COST

DNREC's Small Systems Branch (personal communication, 2006) revealed that the installation of best available technologies (BATs) to existing small (<2,500 gallon per day (gpd)) OWTDSs for advanced nitrogen removal would cost between $3500 and $6000 per system with an average of $4,750. These technologies require a service contract by a certified service provider with an estimated annual cost that ranges from $150 to $300, with an average cost of $225/system/year. In addition, the systems will still require pump-outs, which cost $64/system/year (DNREC small System Branch, personal communication, 2007), and they will need periodic mechanical parts repaired, estimated to cost $50/system/year and the electric cost of running the system is likely to also cost about $50/system/year (DNREC Financial Assistance Branch, personal communication, 2007). Costs are not currently available for the retrofit of larger systems.

The cost of these systems will be paid by the land owner. Cost-share funds may be found to assist those of middle-income and below. At present, State Revolving Fund (SRF) money and Septic Rehabilitation Loan Program funds may be used to provide low interest loans to property owners that need to replace a failing system.

ACTION

With the promulgation of the new proposed regulations governing the design, installation, and operation of on-site wastewater treatment and disposal systems regulations by the end of 2010, the Department believes that this recommendation on performance standards will be met. If the new on-site wastewater treatment and disposal systems regulations are not promulgated as anticipated, the Department will promulgate the necessary regulations for this recommendation.

## *Education*

*The State, County and local governments should work together to develop and disseminate homeowner education materials. The materials should inform septic system owners about proper maintenance of their septic systems, and be based on the system type that is used, such that nutrient loading from the system is minimized. The materials should emphasize the dual benefits of proper system maintenance to both homeowner and watershed.*

COMMENTARY
The Department agrees that education will be an important aspect to septic system maintenance and has already worked on outreach materials. The Department has developed a brochure "Simply Septic" to educate homeowners on the operation of septic systems. In order to change the behaviors of the public on septic systems, they need to be informed about how these systems function and how they need to be maintained. The brochure provides valuable information on good housekeeping of septic system and also provides handy tips to increases the longevity of septic system. The brochure is available on DNREC's webpage and is easily accessible for anyone.

AUTHORITY
Not an issue for this recommendation.

NUTRIENT REDUCTIONS
Good housekeeping of septic systems helps reduce nutrient loadings; however the Department is currently unable to estimate nutrient reduction from this activity.

COST
The cost for the implementation depends on the level of outreach program and staff time needed to implement program. The outreach programs can be workshops, educational brochures/ materials, fact sheets and/or trainings.

ACTION
The Department will continue to work with the county and local governments on providing educational outreach.

## RESIDENTIAL BEHAVIOR

*Establish guidelines that promote good lawn and yard stewardship through best management practices, including organic methods of care, for better nutrient management and water quality. These guidelines should be disseminated throughout the watershed by DNREC and the Department of Agriculture. Brochures could be placed in stores that sell yard materials, restaurants, and in other public places and passed out at community events.*

COMMENTARY
The Nutrient Management Commission has developed best management practices for commercial and residential turf management. These do not include organic methods of care. Organic methods would need to be further studied. Also, the Nutrient Management Commission has completed brochures on home lawn care. They have spent months on these and have involved numerous experts. They have contacted retail stores that sell fertilizers and gained permission to display and distribute them. The NMC would be willing to work with partners to increase circulation in the watershed.

AUTHORITY
The Nutrient Management Commission has authority over those who apply nutrients to areas of 10 acres or greater. Coordinating and partnering with them on home lawn care issues will ensure that the message is spread in an efficient manner.

NUTRIENT REDUCTION
Although this recommendation is believed to help reduce nutrient pollution, the Department cannot attach specific nutrient reductions.

COST
Cost would depend upon the number of brochures printed. The Commission has already printed 31,000 copies.

ACTION
Although the recommendation has been mostly implemented, the Department would be willing to explore producing a brochure on organic methods of care.

*The State should work with the University of Delaware Soils Lab to revise the soil test result sheets that go to homeowners in order to make them more understandable and easily implemented by the lay public. The State should also work with the Cooperative Extension Service to assist in disseminating soil test kits.*

COMMENTARY

The Department understands the need for more user-friendly soil test result sheets. The University of Delaware soils lab has been sending out recommendations along with the soil results since they started in 1947 and have been updated as needed. The Department wants to work with the University to provide education on types of fertilizer to use. This recommendation has been made in the past by other Tributary Action Teams. The Department did sent a copy of the user friendly test results to the University; however, no one has made any suggestions for how to follow through with the changes. Another effective way to educate the public might be to work with home improvement stores and fertilizer companies to make the fertilizer bags more understandable and consistent with the soil test recommendations.

NUTRIENT REDUCTIONS

Although this recommendation is believed to achieve nutrient reductions, the Department is unable to provide a number at this moment.

COST

Not available at this time.

ACTION

The Department will continue working with the Soil Lab to make the recommendation user friendly and will work with partners to identify specific suggestions to improve user friendliness of the report.

*Local governments should develop appropriate code changes and distribute guidelines, through consultation with the State, for alternative lot landscaping that will reduce surface water runoff. Information should be given to homeowners at the time of settlement.*

COMMENTARY

The Department may be able to contract with a consultant to develop the guidelines. Then, New Castle County, Middletown, Odessa, and Townsend codes may need to be revised to allow this type of landscaping, given that the code discusses landscaping and sets standards. Funding this project may be difficult given the current budget situation.

Voluntary programs have already been implemented in the watershed through Smartyards. Partnering with the Delaware Nature Society, the ARA provided 20 backyard habitat kits in fall 2004 and 20 kits in spring of 2005 to residents in the Appoquinimink Watershed. Smartyards is a unique component of the Delaware Nature Society's Backyard Habitat program, through which participants discover how to provide an oasis for local birds, butterflies, and other wildlife while helping to ensure the health of our streams and rivers.

At no cost to participants, Smartyards provides official certification for properties where owners meet the four criteria necessary for wildlife habitat: food, cover, water, and places for wildlife to raise young. Certified habitats may range from those meeting the minimum requirements, such as a small urban balcony or rooftop, to extensive naturalized areas that meet a variety of wildlife needs. By adopting practices beneficial to wildlife such as planting native species, limiting use of chemical fertilizers and pesticides, reducing the size of lawn areas, and better maintaining small areas of forest or wetlands if located in backyards, participants help to improve local water quality. Smartyards provide habitat for a greater diversity of wildlife species, prevent the pollution of runoff from urban and suburban yards, and reduce the quantity of runoff more than traditional turf grass landscapes. Participants begin to make the connection that the wildlife in their yards is a part of the natural environment of their community, which includes the Appoquinimink River and its streams and tributaries.

The Appoquinimink River Association has also begun a Community Wildlife Habitat program in Townsend. This program provides habitat for wildlife throughout a community – in individual backyards, on school grounds and in public areas such as parks, community gardens, places of worship and businesses. Residents make it a priority to provide habitat for wildlife by providing the four basic elements that all wildlife need including food, water, cover, and places to raise young. The program also educates residents about sustainable gardening practices such as reducing or eliminating chemical fertilizers and pesticides, conserving water, planting native plants, removing invasive plants, and composting.

AUTHORITY

New Castle County and the local governments may need to amend their codes and ordinances in order to implement this recommendation. If it is mandated that the information be given at settlement, then real estate law would need to be changed. However, if the information is well-distributed and marketed, this would not be necessary.

NUTRIENT REDUCTIONS

Based on preliminary data on installations of 1,000 square feet each, the installation of Smartyard landscaping in residential lawns has shown nutrient reductions of 0.11 lbs of nitrogen per acre per year and 0.04 lbs of phosphorous per acre per year.

COST

The average cost of installing Smartyard landscaping in residential lawns in the Appoquinimink Watershed has been $956.20 per ¼-acre yard. This is an average of the total costs of 20 projects in the fall of 2004 and 20 projects in spring of 2005. Therefore, based on this initial cost, the cost of the nutrient reductions is $34,933/lb N and $95,272/lb P on an annual basis. These high costs are obviously excessive per pound of nutrients reduced because of the first year’s cost of installation, staff time and educational materials. The annual maintenance and operation costs will undoubtedly be a small fraction of the original installation cost, so the nutrient reduction cost should decrease considerably in successive years.

ACTION

The Department will work with partners including the County and local governments to apply for federal grants for this work.

*Explore the possibility of providing nutrient management education and training for those who sell fertilizers in retail outlet. This would include working with retailers to see that a stick-on label be placed on all bags of fertilizers sold in the watershed warning that the overuse or improper use of fertilizers harms our ground and surface waters.*

COMMENTARY
Educating property owners on the wise use of fertilizers can lead to fewer applications of nutrients to developed lands, and result in fewer nutrients reaching ground and surface waters. Annual state-wide fertilizer sales data indicate that fertilizer sold for non-farm uses has increased from 4,816 tons in the 1994-1995 period (3.9% of the total fertilizer sales) to 17,793 tons in the 2007-2008 period (12.8% of the total fertilizer sales). Thus, the fertilizer being applied to developed areas is 3.5 times greater now than it was 14 years ago. Between 2000 and 2008 in New Castle County, the percentage of total fertilizer sold for non-farm uses ranged from 28.4% to 71.2% and averaged 43.5%. This data reflects the larger percentages of developed areas in New Castle County versus the rest of the state. It is clear that fertilizers are being applied to developed areas and better education on the proper use of fertilizers would be beneficial, especially in New Castle County.

AUTHORITY
Not an issue.

NUTRIENT REDUCTION
Although this recommendation is believed to help reduce nutrient pollution, the Department cannot attach specific nutrient reductions.

COST
Not available at this time.

ACTION
The Department will work with partners, including the Nutrient Management Commission and local retailers to make this a reality.

*All environmental information should be supplied periodically on the scrolling band under the picture on the Weather Channel. DNREC should find the money to pay for this if cable providers will not do it as a public service.*

COMMENTARY
This would be an excellent way to keep the public informed as to environmental issues of importance around the State. This form of outreach program is very expensive and may not be possible in the near future due to the tight budget situation of the Department. However, the Appoquinimink Watershed Coordinator is actively involved in publicizing environmental work

done in the watershed. The watershed has received media recognition in the *News Journal*, *Middletown Transcript,* and various newsletters.

AUTHORITY
Not an issue.

NUTRIENT REDUCTION
With the public awareness, there may be some nutrient reduction; however the Department is not currently in a position to estimate a nutrient load reduction.

COST
As already mentioned, this form of outreach is very expensive and actual costs depends on how frequent the information is publicized.

ACTION
Although it is expensive to work with the media, the Department will work with the Appoquinimink River Association to implement this recommendation.

## *The County and State should re-establish a groundwater monitoring program for southern New Castle County to ensure the quality of our drinking and surface water.*

COMMENTARY
In July 1994, the Delaware Geological Survey (DGS), in cooperation with the Water Resource Agency, New Castle County Department of Public Works, Delaware Division of Public Health, Delaware Department of Natural Resource and Environmental Control, and Department of Agriculture, designed a multi-phase groundwater quality monitoring network for southern New Castle County. The sampling was established in August 1996 and was completed in June 1997. The study showed anthropogenic agricultural impacts, specifically elevated nitrate and detectable pesticide concentrations.

AUTHORITY
The Groundwater Monitoring Network of Water Supply Coordinating Council has the authority to monitor the wells.

NUTRIENT REDUCTIONS
There is no direct relation to the nutrient reduction with the groundwater monitoring network. However, the network will collect data in support of groundwater modeling to determine occurrence, availability, quality, and quantity of water in the wells. Additionally, the data can be used to help track the effects of various BMPs. This information may be used to emphasize nutrient reduction programs in areas where nutrient concentrations are high.

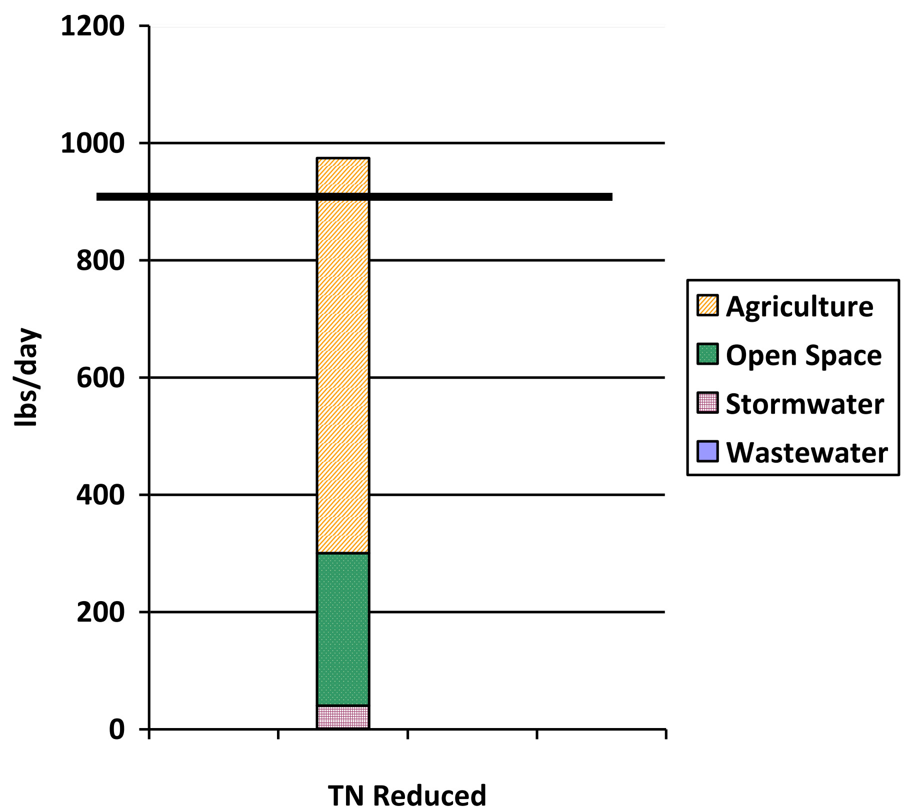
COST
Costs are unknown at this time.

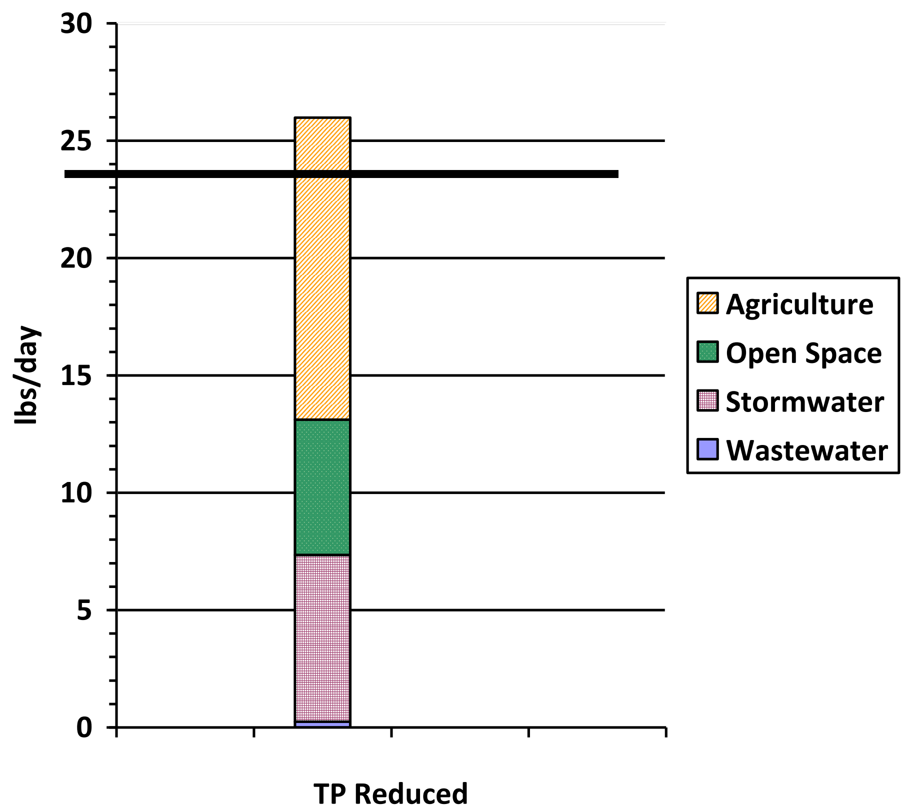
# ANALYSIS FOR TMDL ACHIEVEMENT AND COST

Promulgation of this Pollution Control Strategy and full implementation of its elements should lead to the achievement of the TMDLs for Total Nitrogen (TN) and Total Phosphorus (TP). Because of the lag time between seeing improvements in ground and surface water quality, estimated to be up to 30 years, improved water quality conditions will not be realized immediately. The Department will continue to monitor water quality as will many citizen volunteers. The Department is committed to revisit this Pollution Control Strategy in 10 years to ensure that water quality is improving with implementation of the regulations and voluntary practices called for within this document.

Analysis using a basic land use loading rate model shows that, to date, nonpoint sources of TN and TP have been reduced by 109% and 111%, respectively (Figure 3). Thus, voluntary programs for installation of agricultural best management practices have been extremely successful as well as the County's and local governments' efforts to protect open space and riparian buffers. Implementation of the Sediment and Stormwater Law has also led to decreases in nutrient loading, however, the full impact is not shown here because some sediment and stormwater practices, known to be in place, are not yet captured in a database and therefore, not considered in these calculations.

Figure 3: TMDL Progress to Date

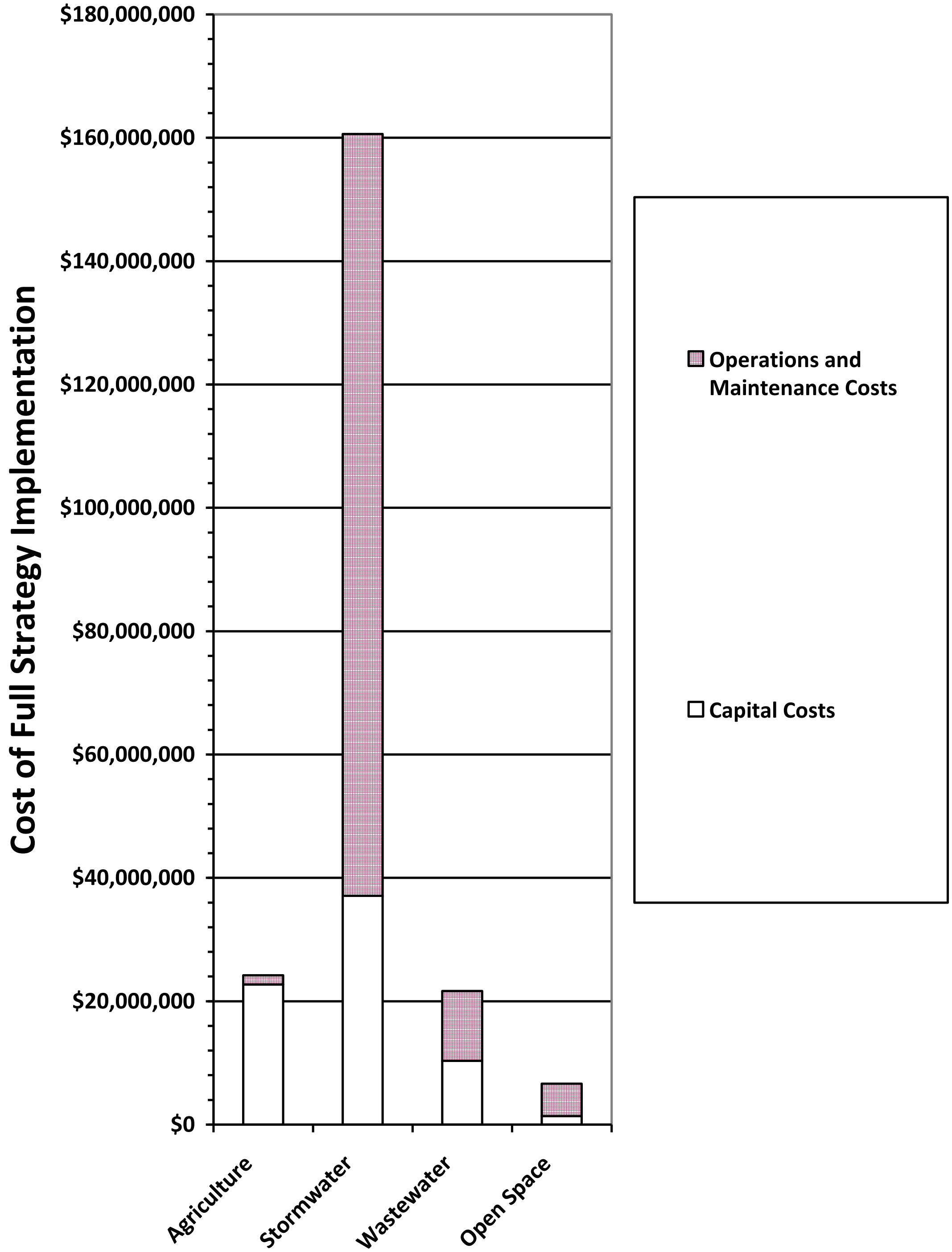





While current implemented practices have been shown to reach the required reductions, it is important to note that there are practices that are still necessary to keep the watershed healthy and meeting it's TMDL. The most important area for future implementation is wastewater. This includes requiring existing septic tanks to be pumped out at time of property transfer and preferably once every three years, continuing to connect existing septic tanks to sewer systems and implementing technologies that will allow systems to meet performance standards to remove nutrients. In addition, realizing that development is still occurring throughout the watershed and stormwater best management practices are required, future BMP implementation must move away from practices that only deal with water quantity, but also provide significant water quality benefits. Also, the strategy is based on the maintenance of agricultural practices currently in place as well as the continued push towards open space and riparian buffer preservation.

Overall, this strategy costs over $213,000,000 including capital expenditures plus annual operation and maintenance costs of various best management practices. Of this strategy total, about $45,000,000 (about 25%) has already been paid for the installation of current practices and $168,000,000 is just for the installation and maintenance of future practices. Figure 4 shows the total strategy costs for each category of BMP including current and future practices.

Figure 4: Total Strategy Implementation Costs




Every effort has been made to make the Strategy fair and equitable. It impacts everyone in the watershed given that all activities contribute to nutrient loading. And, it attempts to take cost into consideration through promoting the least expensive actions and cost-share for those actions that are more expensive. The Department intends to review the Strategy in 10 years and update it if further actions are needed to improve water quality.

## IMPLEMENTATION PROGRAMS

Pollution of the Appoquinimink River did not happen over a short period of time, nor did it only happen due to the actions of a few people. Thus, implementing the Pollution Control Strategy will necessitate participation from a broad variety of programs, agencies, nonprofit, and community organizations. These programs will provide technical, financial, and administrative assistance in the effort to clean up these waters.

***Appoquinimink River Association***

In order to allow any interested citizen to participate in the process of reducing pollution in their neighborhood waters, DNREC created the Appoquinimink Tributary Action Team in 2000. Comprised of local educators, scientists and landowners, this group spent the next couple of years discussing and developing detailed recommendations on how the 20% nutrient reduction required by the TMDL could be achieved in the watershed.

Following the issuance of the second Appoquinimink TMDL in December 2003, the Team initiated further discussion of ways to reach the TMDL that now required a 60% nutrient reduction. As a result of the intensive dialogue, the team decided that it was necessary to transition the group into a separate nonprofit organization to be able to best address the needs of the watershed. Thus, in April 2004 the Appoquinimink River Association was incorporated in the State of Delaware under the mission of working to preserve, protect and enhance the rivers and related natural resources of the Appoquinimink region.

As the Association began to work more on projects throughout the watershed, they realized the benefits of expanding into a organization that helps preserve, protect and enhance the water resources and natural areas of all the watersheds of southern New Castle County. To begin implementing this vision, in 2009 the Association increased their education, outreach and project implementation throughout southern New Castle County.

***Coastal Nonpoint Program – 6217***

The Coastal Nonpoint Program was established by Congress in 1990 under section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA) to ensure that coastal states have the tools needed to address polluted runoff. A consistent set of management measures was established for states to use in controlling polluted runoff. Management measures are designed to prevent polluted runoff resulting from a variety of sources. The program includes enforceable policies and mechanisms to ensure implementation of the measures. The Delaware Coastal Nonpoint Program is administered in the State of Delaware by the Delaware Coastal Programs in the Division of Soil and Water Conservation of the Department of Natural Resources and Environmental Control. Delaware's Coastal Nonpoint Program is a networked program with implementation responsibilities distributed throughout the State. The Delaware Coastal Programs receives an annual award used to aid in the implementation of management measures, program initiatives and the funding of grants for projects designed to preserve and protect Delaware's waterways from the degradation of nonpoint source pollution. Through cooperative efforts will both government agencies and local organizations, numerous projects have been designed and funded to help address issues concerning nonpoint source pollution in Delaware.

***The Delaware Forest Service***
The Delaware Forest Service is a section of the Delaware Department of Agriculture and is charged to improve and enhance the state rural and urban forest resources. Delaware's Forest Service staff, through the Urban and Community Forestry Program, provides technical, educational and financial assistance to cities, towns, communities, developers and local governments to develop a community forestry management plans and resource evaluation studies. Foresters also review new planned subdivisions in order to conserve forest resources. Additionally, the program provides annual grant assistance to a variety of partners to provide both tree planting and tree care activities. Also, the professional foresters help private and public landowners to improve their forest resources through a variety of services. This technical assistance encompasses a wide range of forest management activities including reforestation, timber stand improvements, timber harvesting and forest management plan development.

***DNREC -- Groundwater Discharges Section***
Located within the Division of Water Resources, the Groundwater Discharges Section is responsible for overseeing all aspects of the siting, design and installation of on-site wastewater treatment and disposal systems. This is a three step process which includes the site evaluation, the design/permit application and the construction/installation of the system. The Small Systems Permitting Branch reviews and approves site evaluations, permit applications and conducts inspections of system installations. Experimental/alternative technologies and advanced treatment units are approved and permitted for use by the Large Systems Permitting Branch. The Section is also responsible for the permitting of underground injection wells, large spray irrigation wastewater systems, and other means associated with land application wastewater treatment. The Section also issues waste transporter permits and licenses to designers, percolation testers, site evaluators and system installers.

***DNREC – Nonpoint Source Program***
The Delaware Nonpoint Source Program (NPS) administers a competitive grant made possible through Section 319 of the Clean Water Act. It is housed under the Division of Soil and Water Conservation within the Department of Natural Resources and Environmental Control. The grant provides funding for projects designed to reduce nonpoint source pollution in Delaware. NPS pollution may be defined as any pollution that originates from a diffuse source (such as an open field or road) and is transported to surface or ground waters through leaching or runoff. Reduction of NPS pollution, but most frequently involve agriculture, silvilculture, construction, marinas and septic systems. Proposals are reviewed and evaluated, and those which are determined to meet specific requirements are eligible for funding. All projects must include matching funding from a non-Federal source totaling at least 40 percent of the overall project cost. In addition to funding projects that achieve reductions in NPS pollution, the Delaware NPS Program is committed to addressing the issue through educational programs, publications and partnerships with other organizations working to reduce NPS pollution in Delaware.

***DNREC-Sediment and Stormwater Program***
The Sediment and Stormwater Program is managed by the Division of Soil and Water Conservation in the Department of Natural Resources and Environmental Control. Delaware's stormwater management program requires sediment control during construction and post-construction, stormwater quantity and water quality control. This program functions from the

time construction begins through a project's lifespan. It requires construction and development projects to obtain sediment control and stormwater plan approval, be inspected during construction, and a post-construction inspection of permanent stormwater facilities and education and training. The program's initial emphasis is to prevent existing flooding or water quality from worsening and limit further degradation until more comprehensive, watershed approaches (as detailed in State legislation and regulations) are adopted. Current regulations require stormwater management practices to achieve an 80 percent reduction in total suspended solids load after a site has been developed. This is achievable with present technology. Long-term removal rates over 80 percent may require other measures, such as water re-use, which may be required locally. In Delaware, day-to-day inspection responsibilities are handled by the delegated local agency, but projects where site compliance is not possible are handled by the State with progressive and aggressive enforcement, including civil and criminal penalty provisions.

***DNREC - Surface Water Discharges Program***

The Surface Water Discharges Program is delegated to the Division of Water Resources in the Department of Natural Resources and Environmental Control. Program administrators are responsible for eliminating pollutant discharges into State surface waters by issuing regulatory permits under the National Pollutant Discharge Elimination System (NPDES). An NPDES permit legally sanctions the discharge of substances that may become pollutants. However, the NPDES permit is designed to limit the discharge of those substances so that there will be no adverse effect on the quality of the receiving waters or interference with the designated uses of those waters. The health of a water body is measured by its attainment of designated uses. If potential pollutants in a NPDES discharge are reduced to levels that allow receiving waters to meet applicable designated uses, then, in effect, the pollutant discharge has been eliminated.

Municipal sewage treatment or industrial plants that discharge wastewater to surface waters of Delaware are issued permits specifying discharge limitations, monitoring requirements and other terms and conditions that must be met to be allowed to discharge. In addition to wastewater, wastewater facilities often generate a waste sludge solid that is also an NPDES discharge under federal and State regulations. The NPDES General Permit for "stormwater discharges associated with industrial activities," a single permitting regulation with requirements that apply to a group of similar dischargers is also issued to industrial sites that discharge only stormwater.

***DNREC – Water Supply Section – Groundwater Protection Branch***

This program is responsible for providing technical review of permit applications for non-hazardous waste sites (i.e. large septic, wastewater spray irrigation, sludge application) and for water well permit applications where wells are located near problem sites. Staff hydrologists conduct investigations based on public complaints of groundwater quality, often associated with domestic water wells.

The Source Water Protection Program (SWPP) has been delegated to DNREC and is managed by the Water Supply Section, Groundwater Protection Branch of the Division of Water Resources. This program was created from the 1996 Amendments from the Safe Drinking Water Act. The SWPP is responsible for determining the locations of water supplies used for public drinking water. The program is also responsible for mapping the wellhead protection areas (those areas around a well or group of wells from which a source obtains within those delineated areas, and determining the susceptibility of the drinking water source to contamination. The SWPP is required to make this information available to the public and does so through the program's website: www.wr.udel.edu/swaphome/index.html.

Through the Source Water Protection Law of 2001, the SWPP was charged with the development of a guidance manual for the protection of source water areas. This manual was development to give the counties and those municipalities containing 2000 or more persons) ideas on methods that could be used to protect those areas by 2007.

***Local Governments***

County and local governments have the authority to enact ordinances to further the goals of this Pollution Control Strategy. They are all required to complete Comprehensive Plans and address how they intend on assisting in the implementation of the TMDLs. Many of these entities have ordinances that require buffers, open space and maximum impervious coverage – ordinances that work towards achieving water quality standards. Local governments within the TMDL watershed include: New Castle County, Town of Middletown, Town of Townsend and Town of Odessa.

***Nutrient Management Commission***

The Delaware Nutrient Management Program was established as a result of the Delaware Nutrient Management Law. The Delaware Nutrient Management Commission (DNMC) was established to direct the program and develop regulations pertaining to nutrient management, waste management for Animal Feeding Operations (AFOs) and National Pollutant Discharge Elimination System (NPDES) permits for concentrated animal feeding operations (CAFOs). The DNMC manages activities involving the generation and application of nutrients in order to help maintain and improve the quality of Delaware's ground and surface waters to help meet or exceed federally mandated water quality standards in the interest of the overall public welfare. All persons who operate an animal feeding operation in excess of 8 animal units (1 AU = 1,000 pounds) and/or control/manage property in excess of 10 acres where nutrients are applied must develop and implement a nutrient management or animal waste plan. The DNMC provides cost assistance programs, certifications and investigation of complaints.

***Office of State Planning Coordination***

The mission of the Office of State Planning Coordination (OSPC) is "the continuous improvement of the coordination and effectiveness of land use decisions made by state, county and municipal governments while building and maintaining a high quality of life in the State of Delaware." Under the new PLUS (preliminary land use service) process, the OSPC will bring together State agencies and developers early in the development process in order to try to identify and mitigate potential impacts. The OSPC also supports the Governor's "Livable Delaware" initiative and has published *Better Models for Development in Delaware* that includes many best management practices which will be needed in order to achieve the TMDL.

***Soil and Water Conservation Districts***

County Conservation Districts were created by State law and are administer through Delaware Natural Resources and Environmental Control. They operate the State Conservation Cost Share Program which provides funds for installation of agricultural management practices, promote the State Revolving Loan Fund Program for poultry producers (low-interest loans to implement best management practices) and are the delegated agencies for the Sediment and Stormwater Management Program carrying out plan review and field inspections in their respective counties. Watersheds prioritized by Delaware’s Nonpoint Source (Section 319) Pollution Program can be targeted by these activities.

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# APPENDIX A

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

# Total Maximum Daily Load For Nutrients and Dissolved Oxygen for the Appoquinimink River

/S/

**Jon M. Capacasa, Director**
**Water Protection Division**

**Date: 12/15/2003**

# Nutrient and Dissolved Oxygen TMDL Development for Appoquinimink River, Delaware

**December 2003**

U.S. Environmental Protection Agency
Region 3
1650 Arch Street
Philadelphia, Pennsylvania

# Table of Contents

## Executive Summary

The Appoquinimink River watershed drains approximately 47 square miles in New Castle County, Delaware, and is primarily agricultural with three residential/urban centers (Middletown, Odessa, and Townsend). The area is experiencing significant residential growth. The topography is generally characterized by flat to gently sloping land which is typical of the coastal plain. The Appoquinimink River system consists of three main tributaries, the Appoquinimink River main stem, Deep Creek, and Drawyer Creek. There are several shallow, man-made small lakes and ponds in the watershed (Wiggins Mill Pond, Noxontown Lake, Silver Lake, and Shallcross Lake). The Appoquinimink River is designated as a warm-water fishery and is subject to all water quality criteria specific to this designated use and those defined for general statewide water uses including aquatic life, water supply, and recreation. Due to their high nutrient concentrations and/or low dissolved oxygen levels, the Delaware Department of Natural Resources and Environmental Control (DNREC) identified and included in the state's 1996, 1998, and 2002 Section 303(d) lists of impaired waters several portions of the Appoquinimink River.

The Environmental Protection Agency Region III (EPA) establishes these Total Maximum Daily Loads (TMDLs) for the Appoquinimink River basin to address those stream segments impaired as a result of excess nutrients and low dissolved oxygen (DO). To address nutrient impairments, TMDLs have been established for total nitrogen (TN) and total phosphorus (TP) in order to attain and maintain applicable Water Quality Standards (WQS). There are presently no nutrient criteria defined by WQS for streams in the Appoquinimink River basin. Of the components of instream biological activity, only DO concentrations are included in water quality standards for stream segments of the Appoquinimink River basin. As a result, the nutrient TMDL endpoint is based on both the minimum and minimum daily average DO for the critical summer period characterized (June through September).

As part of the nutrient TMDLs, EPA has allocated specific amounts of TN and TP to nonpoint sources and point sources covered under storm water permits and flow, carbonaceous biochemical oxygen demand (CBOD), total kjeldahl nitrogen (TKN), and TP to the Middletown-Odessa-Townsend (MOT) WWTP located in the watershed. These allocations are necessary to restore and maintain applicable WQS for DO in the Appoquinimink River watershed.

TMDLs were determined for impaired segments and the subwatershed(s) contributing to them during the critical summer period (June through September). The total TMDL for each impaired segment is the combination of all TMDLs for contributing subwatersheds and for the MOT point source, where applicable. These watershed-based loads and the allocated load for the MOT WWTP enable the in-stream DO concentrations to meet criteria under all conditions. It should be noted that the WLAs for the storm water permits and the LAs for areas not covered by the storm water permits have been combined into a single WLA for each subwatershed (and impaired segment) and have not been presented separately. DNREC and New Castle County are currently in the process of mapping storm water discharge locations that are covered by the permits, and as such, insufficient data are currently available to justify a more detailed allocation to the storm water permits. Once the mapping effort on behalf of DNREC and the county is complete, the TMDL can be refined to distribute the TMDL among the storm water permits (WLAs) and the nonpoint sources (LAs). The margin of safety (MOS) for this study was assumed implicit through conservative assumptions used in the modeling process.

The following tables summarize the TMDLs to address nutrient impairments for each stream segment of the Appoquinimink River basin included in the State's 303(d) list.

**Table ES-1.** TMDLs by contributing subwatershed for impaired waters of the Appoquinimink.

| Segment Name | Segment ID | Contributing Subwatershed(s) | WLA TN (lbs/yr) | WLA TP (lbs/yr) |
|---|---|---|---|---|
| Appoquinimink River (Lower) | DE010-001-01 | 1 | 14,074 | 1,707 |
| | | 2 | 6,737 | 896 |
| | | 3 | 1,547 | 231 |
| | | 4 | 7,075 | 862 |
| | | 5 | 7,388 | 1,024 |
| | | 6 | 5,498 | 742 |
| | | 7 | 6,954 | 874 |
| | | 8 | 10,594 | 1,367 |
| | | 9 | 5,366 | 693 |
| | | 10 | 8,814 | 1,230 |
| | | The total TMDL for this segment also includes the WLAs for the MOT WWTP (Table ES-2) | | |
| Appoquinimink River (Upper) | DE010-001-02 | 2 | 6,737 | 896 |
| | | 5 | 7,388 | 1,024 |
| | | 6 | 5,498 | 742 |
| | | 7 | 6,954 | 874 |
| | | 8 | 10,594 | 1,367 |
| | | The total TMDL for this segment also includes the WLAs for the MOT WWTP (Table ES-2) | | |
| Drawyer Creek | DE010-001-03 | 1 | 14,074 | 1,707 |
| | | 9 | 5,366 | 693 |
| | | 10 | 8,814 | 1,230 |
| Wiggins Mill Pond to confluence with Noxontown Pond | DE010-002-01 | 5 | 7,388 | 1,024 |
| Deep Creek to confluence with Silver Lake | DE010-002-02 | 7 | 6,954 | 874 |
| Noxontown Pond | DE010-L01 | 5 | 7,388 | 1,024 |
| | | 6 | 5,498 | 742 |
| Silver Lake | DE010-L02 | 7 | 6,954 | 874 |
| | | 8 | 10,594 | 1,367 |
| Shallcross Lake | DE010-L03 | 10 | 8,814 | 1,230 |

**Note:** A map of the Appoquinimink River basin and its subwatersheds is presented in Section 4.0

**Table ES-2.** WLAs for the MOT WWTP NPDES discharge (DE0050547).

| Parameter | WLA |
|---|---|
| Flow | 0.5 mgd |
| CBOD-5 day | 34.8 lbs/day (12,702 lbs/year) |
| Total Kjeldahl Nitrogen (TKN) | 10.4 lbs/day (3,796 lbs/year) |
| Total Phosphorus (TP) | 2.1 lbs/day (766.5 lbs/year) |

The TMDL represents one allocation scenario. As implementation of the established TMDL proceeds, DNREC may find that the applicable water quality standard can be achieved through other combinations of point and nonpoint source allocations that are more feasible and/or cost effective. If that happens, DNREC is free to re-run the model to propose a revised TMDL with an alternative allocation scenario that will achieve water quality standards. It should be noted that, by transferring loadings from one source to another, the results of the model may change even if the total loading remains the same because the proximity and timing of difference sources impacts the river differently.

# 1.0 Introduction

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting their designated uses even though pollutant sources have implemented technology-based controls. A TMDL establishes the allowable load of a pollutant or other quantifiable parameter based on the relationship between pollutant sources and in-stream water quality. A TMDL provides the scientific basis for a state to establish water quality-based controls to reduce pollutant loads from both point and nonpoint sources and restore and maintain the quality of the state's water resources (USEPA, 1991).

Due to their high nutrient concentrations and/or low dissolved oxygen levels, the Delaware Department of Natural Resources and Environmental Control (DNREC) identified and included in the state’s 1996, 1998, and 2002 Section 303(d) lists of impaired waters several portions of the Appoquinimink River. This study will fulfill the requirements for nutrient and dissolved oxygen (DO) TMDLs for all waters in the Appoquinimink River basin included in the State’s 1996 and 1998 303(d) lists.

In 1996, the USEPA was sued under Section 303(d) of the CWA concerning the 303(d) list and TMDLs for the State of Delaware. Ths lawsuit maintained that Delaware had failed to fulfill the requirements of Section 303(d) and the EPA had failed to assume responsibilities not adequately performed by the State. A settlement in the lawsuit was reached and DNREC and EPA signed a Memorandum of Understanding (MOU) on July 25, 1997. Under the settlement, EPA agreed to complete TMDLs for all 1996 listed waters according to a 10-year schedule if the state failed to do so. Under the requirements of the suit settlement DNREC began this TMDL in order to compete the TMDL by December 30, 2002 but, because of various issues, requested EPA to complete the work. Because EPA is developing the TMDL the establishment date, in accordance with the suit settlement agreement, is December 15, 2003.

## 1.1 Background Information

The Appoquinimink River drains approximately 47 square miles in New Castle County, Delaware (Figure 1-1). Major tributaries in the basin include Drawyer Creek and Deep Creek. There are several small, shallow, man-made lakes and ponds in the watershed (Wiggins Mill Pond, Noxontown Lake (pond), Silver Lake, and Shallcross Lake). All tributaries mentioned are included within the listing for the mainstem of the Appoquinimink River on Delaware’s 303(d) list of impaired waters.

The Appoquinimink River watershed is primarily agricultural with three residential/urban centers (Middletown, Odessa, and Townsend). The area is experiencing considerable residential growth. The topography is generally characterized by flat to gently sloping land which is typical of the coastal plain.

The Appoquinimink River is designated as a warm-water fishery and is subject to all water

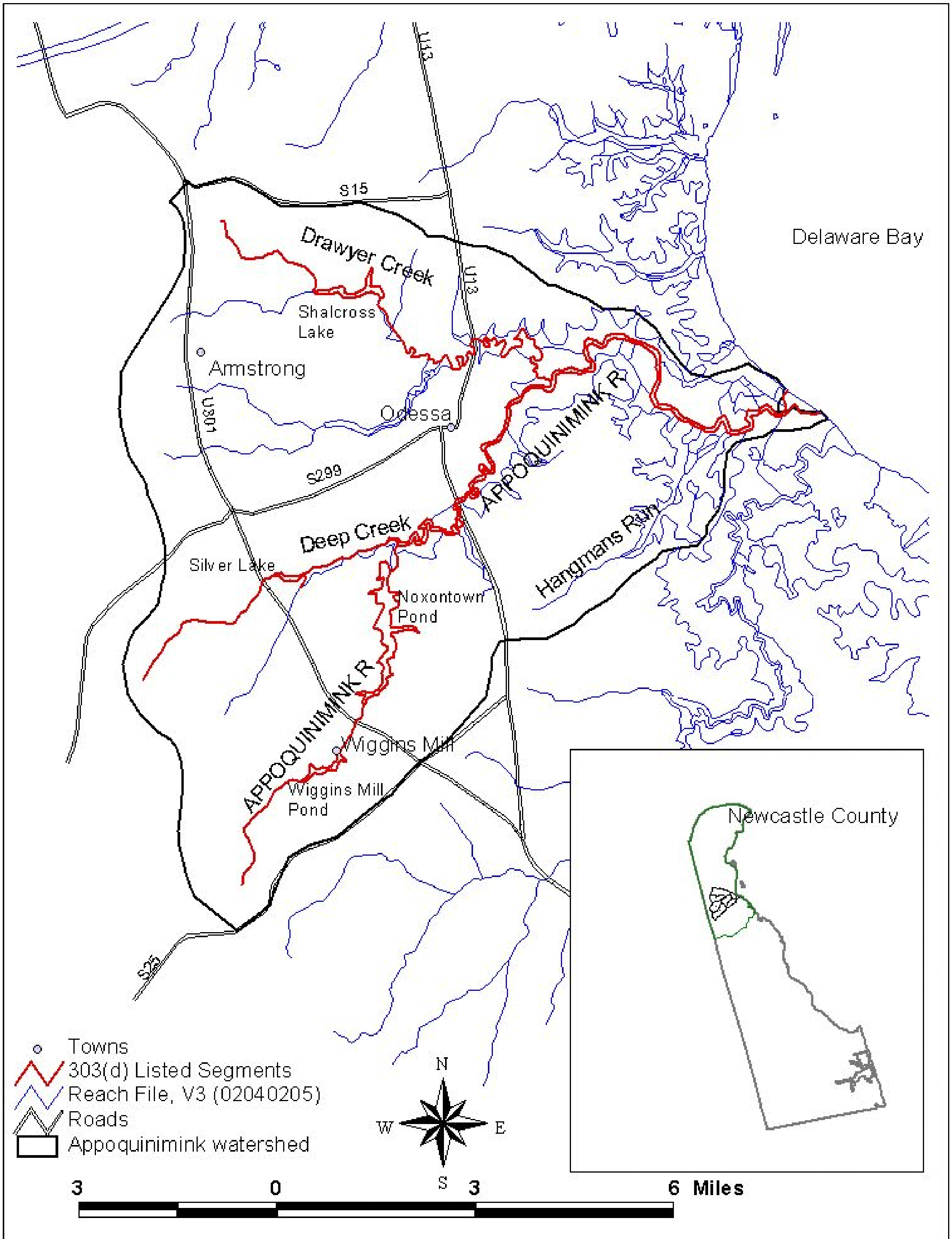




**Figure 1-1.** Appoquinimink River basin; stream segments on 1998 303(d) list are bold (red).

quality criteria specific to this designated use and those defined for general statewide water uses including aquatic life, water supply, and recreation. Several stream segments of the Appoquinimink River basin have been cited on the State's 303(d) list of impaired waters for failing to attain their applicable criteria.

The Appoquinimink River is tidal from the confluence with Delaware Bay to the dam at Noxontown Lake on the main stem, the dam at Silver Lake on Deep Creek, and the confluence with Drawyer Creek. Salinity intrusion from Delaware Bay typically reaches upstream past the Drawyer Creek confluence at river kilometer (Rkm) 8.5. The only non storm water point source in the watershed is the Middletown-Odessa-Townsend wastewater treatment plant (MOT WWTP) located at Rkm 10. Although the MOT WWTP primarily uses spray irrigation to dispose of its effluent, it is also permitted to discharge to the surface waters of Appoquinimink River.

## 1.2 Impairment Listing

TMDL development for this study was limited to nutrient and DO impairments in the Appoquinimink River basin. Eight stream segments in the Appoquinimink River basin were included in Delaware's 1996, 1998, and 2002 Section 303(d) lists due to nutrient and low DO impairments (see Table 1-1 and Figure 1-1). These include 2 segments of the Appoquinimink River mainstem as well as 3 tributary stream segments and 3 small lakes or ponds. Probable sources of nutrients have been identified as the municipal point source and nonpoint source runoff.

**Table 1-1.** Nutrient and DO impaired stream segments of the Appoquinimink River basin.

| Segment Name | Segment ID | Size Affected | Pollutant and/or Stressor | Probable Sources | Year Listed |
|---|---|---|---|---|---|
| Appoquinimink River (Lower) | DE010-001-01 | 7.1 miles | Nutrients, DO | PS, NPS | 1996 |
| Appoquinimink River (Upper) | DE010-001-02 | 6.1 miles | Nutrients, DO | PS, NPS | 1996 |
| Drawyer Creek | DE010-001-03 | 8.2 miles | Nutrients, DO | NPS | 1996 |
| Wiggins Mill Pond to confluence with Noxontown Pond | DE010-002-01 | 3.4 miles | DO | NPS | 1996 |
| | | | Nutrients | NPS | 2002 |
| Deep Creek to confluence with Silver Lake | DE010-002-02 | 2.4 miles | DO | NPS | 1996 |
| | | | Nutrients | NPS | 2002 |
| Noxontown Pond | DE010-L01 | 158.6 acres | Nutrients | NPS | 1998 |
| Silver Lake | DE010-L02 | 38.7 acres | Nutrients | NPS | 1996 |
| Shallcross Lake | DE010-L03 | 43.1 acres | Nutrients | NPS | 1996 |

## 1.3 Water Quality Standards

Section 10 of the State of Delaware Surface Water Quality Standards, as amended August 11, 1999, specifies the following designated uses for the waters of the Appoquinimink River basin: primary contact recreation; secondary contact recreation; fish, aquatic life, and wildlife; industrial water supply; and agricultural water supply (freshwater segments only).

The following sections of the State of Delaware Surface Water Quality Standards, as amended August 11, 1999, provide specific narrative and/or numeric criteria concerning the waters of the Appoquinimink River basin:

(1) Section 3: General guidelines regarding Department's Antidegradation policies
(2) Section 7: Narrative and numeric criteria for controlling nutrient enrichment in waters of the State
(3) Section 9: Specific narrative and numeric criteria for toxic substances
(4) Section 11: General water criteria for surface waters of the State.

Although there are no numeric criteria for nutrients in the waters of the Appoquinimink River basin, Section 7 of Delaware's Surface Water Quality Standards contains the following narrative criteria:

> *Nutrient overenrichment is recognized as a significant problem in some surface waters of the State. It shall be the policy of this Department to minimize nutrient input to surface waters from point and human induced non-point sources. The types of, and need for, nutrient controls shall be established on a site-specific basis. For lakes and ponds, controls shall be designed to eliminate overenrichment. For tidal portions of stream basins of Indian River, Rehoboth Bay, and Little Assawoman Bay, controls needed to attain submerged aquatic vegetation growth season (approximately March 1 to October 31) average levels for dissolved inorganic nitrogen of 0.14 mg/L as N, for dissolved inorganic phosphorus of 0.01 mg/L as P, and for total suspended solids of 20 mg/L shall be instituted. The specific measures to be employed by existing NPDES facilities to meet the aforementioned criteria shall be as specified in Section 11.5(d) of these standards. Nutrient controls may include, but shall not be limited to, discharge limitations or institution of best management practices.*

In the absence of numeric nutrient criteria, DNREC has decided upon threshold levels of 3.0 mg/L for total nitrogen (TN), and 0.1 mg/L for total phosphorus (TP) in determining whether a stream should be placed on the State's 303(d) list of impaired waters.

Section 11 of the Standards contains numeric criteria for DO and the following water quality criteria are applicable to fresh and marine waters of the Appoquinimink River basin:

*General Criteria for Dissolved Oxygen in Fresh Waters*

*(a) Average for the June-September period shall not be less than 5.5 mg/L.*
*(b) Minimum shall not be less than 4.0 mg/L.*

*(c) In cases where natural conditions prevent attainment of these criteria, allowable reduction in dissolved oxygen as a result of human activities shall be determined through application of the requirements in Sections 3 and 5 of these Standards.*
*(d) The Department may mandate additional limitations on a site-specific basis in order to provide incremental protection for early stages of fish.*

*General Criteria for Dissolved Oxygen in Marine Waters*
*(a) Average for the June-September period shall not be less than 5.0 mg/L.*
*(b) Minimum shall not be less than 4.0 mg/L.*
*(c) In cases where natural conditions prevent attainment of these criteria, allowable reduction in dissolved oxygen as a result of human activities shall be determined through application of the requirements in Sections 3 and 5 of these Standards.*
*(d) The Department may mandate additional limitations on a site-specific basis in order to provide incremental protection for early stages of fish.*

According to Section 2 of the Standards, fresh waters are defined as waters of the state which contain natural levels of salinity of 5 parts per thousand (ppt) or less, and marine waters contain natural levels of salinity in excess of 5 ppt. The water quality standards for DO and nutrients are summarized in Table 1-2.

**Table 1-2.** Numeric water quality standards for Delaware.

| Parameter | Comments | Criteria | | Period |
|---|---|---|---|---|
| | | Average (mg/L) | Minimum (mg/L) | |
| Dissolved Oxygen | Fresh waters (i.e., salinity less than 5.0 ppt) | 5.5 | 4.0 | Jun 1 to Sep 30 |
| | Marine waters (i.e., salinity equal to or greater than 5.0 ppt) | 5.0 | 4.0 | Jun 1 to Sep 30 |
| | Both fresh and marine waters | Not specified | 4.0 | Oct 1 to May 31 |
| Ammonia Nitrogen | No numeric criteria; narrative statement for prevention of toxicity. EPA water quality criteria for ammonia nitrogen toxicity used for TMDL. | pH dependent | | year round |
| Nitrate Nitrogen | Maximum contaminant level for public drinking water systems. | 10 mg/L as N | | year round |
| Total Nitrogen | Target for Appoquinimink River basin proposed by DNREC. | 3.0 mg/L as N | | year round |
| Total Phosphorus | Target for Appoquinimink River basin proposed by DNREC. | 0.2 mg/L as P | | year round |

# 2.0 Source Assessment

Analyses were performed on historical water quality and streamflow data to determine critical flow conditions and relative loads to assess the impact of point and nonpoint sources on instream water quality. These analyses helped to assess nutrient and oxygen demanding sources in the Appoquinimink River watershed. Identification of critical flow conditions was an important step in determining the methodology used for TMDL development.

## 2.1 Data Sources

A wide range of information was reviewed for the Appoquinimink River watershed. The categories of data examined include physiographic data describing physical conditions of the watershed, environmental monitoring data identifying potential pollutant sources and contributions to the river and its tributaries, hydrologic flow data, and water quality monitoring data. Table 2-1 summarizes the various data types and data sources reviewed and collected.

**Table 2-1.** Sources of Data for the Appoquinimink River basin.

| Data Category | Description | Data Source(s) |
|---|---|---|
| Watershed Physiographic Data | Land Use (National Land Cover Data) | USGS - MRLC |
| | Stream Reach Coverage (RF 1 and 3, and NHD) | USGS, US EPA BASINS |
| | Digital Elevation Model (30 meter resolution) | USGS - National Elevation Dataset (NED) |
| | Soils | NRCS/USGS STASGO |
| | Weather Information | National Climatic Data Center, National Weather Service |
| Hydrologic data | Stream Flow Data | USGS |
| Water Quality | Instream concentrations of nutrients and oxygen demanding substances as well as other parameters | EPA STORET |

USGS - United States Geological Survey; BASINS - Better Assessment Science; STASGO - State Soil and Geographic Database; DNREC - Delaware Department of Natural Resources and Environmental Control; US EPA - United States Environmental Protection Agency; EPA STORET - STOrage and RETrieval System; RF 1 and 3 - Reach File 1 and Reach File 3; NHD - National Hydrography Dataset

Additionally, a number of technical reports describing past modeling efforts for the Appoquinimink River were reviewed. These include DNREC's *Technical Analysis for the Proposed Appoquinimink River TMDLs - October 2001* and Hydroqual's *The Appoquinimink River Watershed TMDL Model* (2001). The reader is referred to these reports for more detailed data summaries and analysis.

## 2.2 Nutrient and Oxygen Demanding Sources

A review of the historical data collected in the Appoquinimink River basin provided insight into the critical period for impact analysis. Once this condition was identified, the focus was directed to those sources having the most impact during such periods.

### 2.2.1 Identification of Critical Period

Nutrient and DO data have been collected by DNREC at multiple locations in the Appoquinimink River and its tributaries (see Figure 2-1). Concentrations of DO below the water quality standards have been observed at a number of stations, primarily during the summer months (i.e., June through September). Data and past modeling studies indicate that DO levels in the estuarine environment are influenced by contributions of nutrients and organic matter from the watershed (and ultimately the in-stream sediment) throughout the year. The impact from the loadings manifests itself during the summer period (DNREC, 2001). Therefore, the critical period can be influenced by a range of potential sources, including point and nonpoint sources.

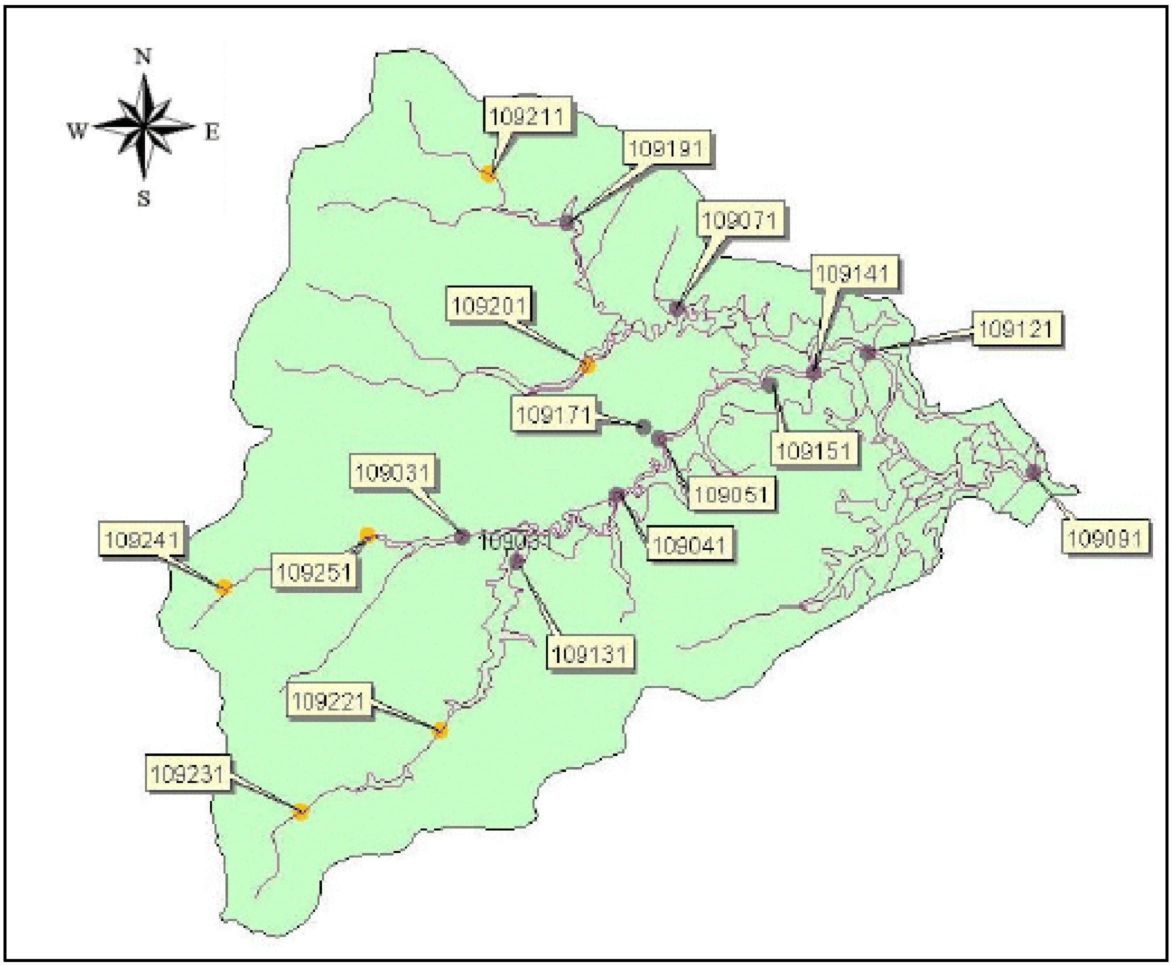


**Figure 2-1.** Monitoring stations in the Appoquinimink River basin.

### 2.2.2 Point Sources

Permitted point sources include discharges such as municipal waste water treatment plants, storm water systems, and industrial waste water facilities. The only non storm water point source discharger to the Appoquinimink River is the Middletown-Odessa-Townsend wastewater treatment plant (MOT WWTP, permit number DE0050547). The permitted and estimated characteristics of the MOT WWTP effluent are summarized in Table 2-2.

**Table 2-2.** Characteristics of MOT WWTP NPDES discharge (DE0050547).

| Parameter | Permit Value | Estimated Value | Load |
|---|---|---|---|
| Flow | 0.5 mgd | | - |
| CBOD-5 day | 34.8 lbs/day | | 34.8 lbs/day |
| Total Kjeldahl Nitrogen (TKN) | 3,796 lbs/year | | 10.4 lbs/day |
| Total Phosphorus (TP) | 2.1 lbs/day | | 2.1 lbs/day |
| Dissolved Oxygen (DO) | | 0.695 mg/L | 2.9 lbs/day |

EPA's stormwater permitting regulations require municipalities to obtain permit coverage for all storm water discharges from separate storm sewer systems (MS4s). Implementation of these regulations are phased such that large and medium sized municipalities were required to obtain storm water permit coverage in 1990 and small municipalities by March 2003. New Castle County has a general storm water permit which includes the municipalities of Middletown, Odessa, and Townsend. These municipalities cover less than 3 percent of the Appoquinimink watershed, but contain most of the watershed's population (4,500 people). The population is expected to expand within the near future. Although the watershed's economy is essentially agrarian, some light industry does exist in Middletown. The MS4 permit for New Castle county covers the major municipalities within the County and the Delaware Department of Transportation. The storm water loadings from the land segments covered by this permit required a waste load allocation (WLA).

### 2.2.3 Nonpoint Sources

In addition to point sources, nonpoint sources may also contribute to water quality impairments in the Appoquinimink watershed. Nonpoint sources represent contributions from diffuse, non-permitted sources. Typically, nonpoint sources are precipitation driven and occur as overland flow that carries pollutants into streams. They can impact a waterbody directly, e.g. through elevated concentrations during storm events and indirectly, e.g. through contribution to bottom sediments and ultimately sediment oxygen demand (SOD).

Land use information from the USGS Multi-Resolution Land Characterization (MRLC) completed in 1992 was available for the Appoquinimink watershed region and was used to evaluate potential nonpoint sources (as well as diffuse sources covered under the storm water permits). Landuse data for 2002 was obtained and used to supplement analysis of the 1992 data. Land use information for the Appoquinimink watershed is summarized in Table 2-3 (for both 1992 and 2002). The 1992 land use distribution for the Appoquinimink River watershed is shown in Figure 2-2.

**Table 2-3.** Landuse in the Appoquinimink River basin.

| Landuse | 1992 | | 2002 | |
|---|---|---|---|---|
| | $mi^2$ | % | $mi^2$ | % |
| Open Water | **1.47** | **3.19** | **1.83** | **3.97** |
| Low Intensity Residential | **0.85** | **1.84** | **6.06** | **13.13** |
| High Intensity Residential | **0.10** | **0.22** | **0.89** | **1.93** |
| High Intensity Commercial/ Industrial/ Transportation | **0.32** | **0.69** | **2.16** | **4.68** |
| Disturbed | **0.03** | **0.07** | **0.92** | **1.99** |
| Forest | **6.17** | **13.37** | **4.06** | **8.80** |
| Pasture/Hay | **8.41** | **18.22** | **1.60** | **3.47** |
| Row Crops | **23.53** | **50.99** | **23.74** | **51.44** |
| Other Grasses (Urban/recreational) | **0.01** | **0.02** | **0.34** | **0.74** |
| Wetlands | **5.26** | **11.40** | **4.55** | **9.86** |
| **Total** | **46.15** | | **46.15** | |

**Note:** The landuse datasets were obtained from different sources. Discrepancies between open water areas are attributable to a difference in the resolution of the datasets or possibly seasonal/hydrologic characteristics.

Based on the landuse data, it is clear that agricultural lands (row crops, in particular) cover a large portion of the watershed. Between 1992 and 2002, there was a significant increase in urban areas and a corresponding decrease in pasture/hay and forested areas. The 1997 Census of Agriculture identifies that the predominant crop types within New Castle County are soybeans, corn, and wheat. It also identifies that within the county, there are approximately 2,698 cattle and calves, 51 hogs and pigs, and 222 sheep and lambs (while chicken numbers are not available).

While a portion of the watershed is sewered, there are also areas that rely on septic systems for sewage disposal. Many of these areas fall outside denoted urban boundaries. Septic systems can contribute pollutants to waterbodies through a number of mechanisms usually associated with failure of the systems. Within New Castle County, there are approximately 12,000 septic tanks or cesspools (based on 1990 U.S. Census Bureau figures).

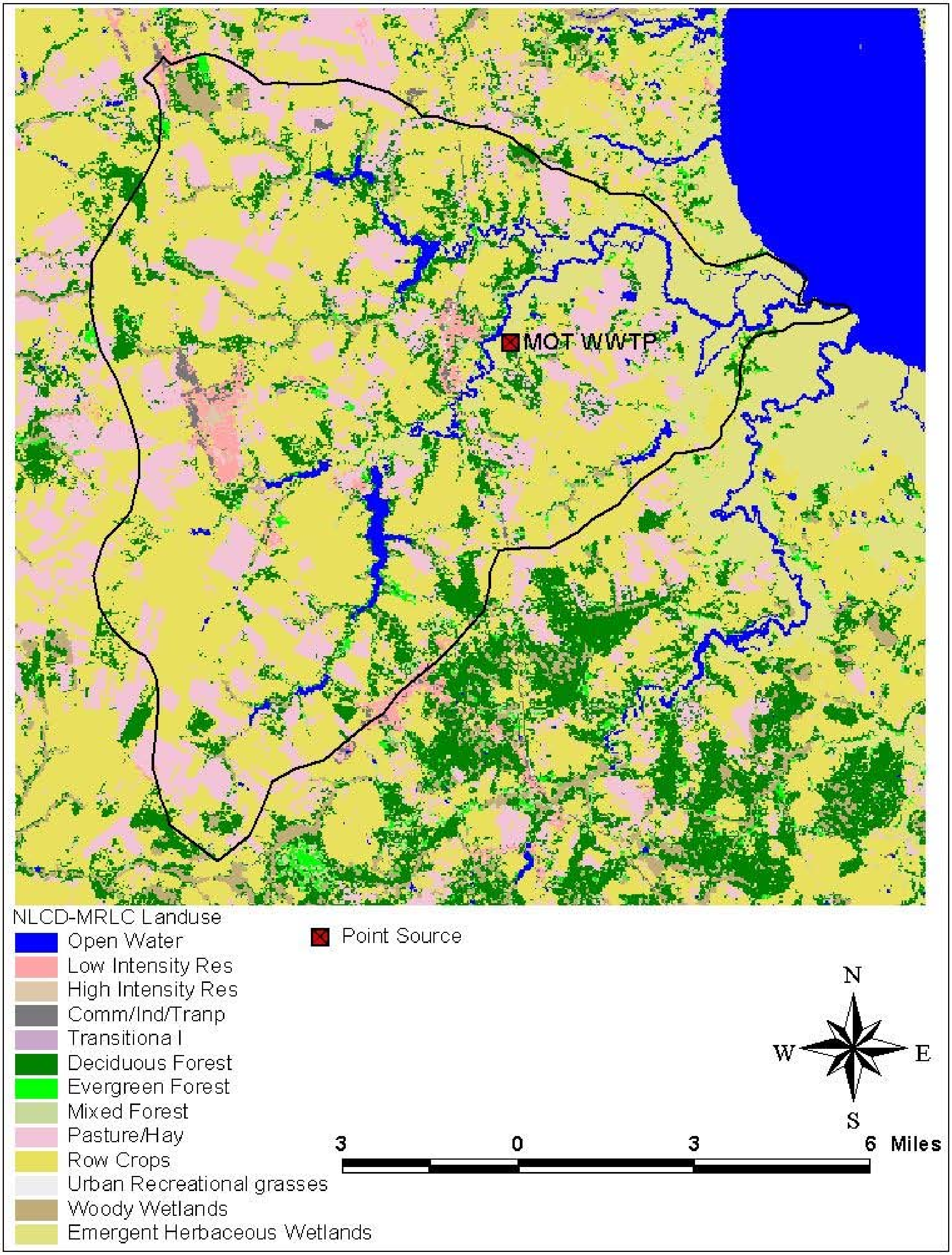


**Figure 2-2.** Land uses in the Appoquinimink River basin.

# 3.0 TMDL Endpoint Determination

The CWA requires states to adopt water quality standards to define the water goals for a waterbody by designating the use or uses to be made of the water, by setting criteria necessary to protect the uses and by protecting water quality through antidegradation provisions. These standards serve dual purposes: (1) they establish water quality goals for a specific waterbody, and (2) they serve as the regulatory basis for establishing water quality-based controls and strategies beyond the technology-based levels of treatment required by sections 301(b) and 306 of the CWA (USEPA, 1994).

Once the applicable use designation and water quality criteria are identified, the numeric water quality target or goal for the TMDL is determined. These targets represent a number where the applicable water quality is achieved and maintained in the waterbody. For the Appoquinimink River TMDLs, the target is to attain and maintain the applicable DO water quality criteria under critical summer conditions. The general water quality targets or endpoints for the Appoquinimink River basin TMDLs are identified in Table 3-1. The fresh water dissolved oxygen criteria was selected for the Appoquinimink River TMDL. The fresh water criteria was chosen because average summer salinity values on the Appoquinimink River were below 5.0 parts per thousand (ppt) upstream of its confluence with Drawer Creek while the minimum salinity values were below 5.0 ppt in the areas downstream of Drawer Creek. This methodology corresponds to DNREC's decision in the *Technical Analysis for the Proposed Appoquinimink River TMDLs* - October 2001.

**Table 3-1.** Summary of TMDL endpoints for Appoquinimink River basin.

| Parameter | Comments | Target Limit | | Period |
|---|---|---|---|---|
| | | Average (mg/L) | Minimum (mg/L) | |
| Dissolved Oxygen | Fresh waters (i.e., salinity less than 5.0 ppt) | 5.5 | 4.0 | Jun 1 to Sep 30 |
| | Marine waters (i.e., salinity equal to or greater than 5.0 ppt) | 5.0 | 4.0 | Jun 1 to Sep 30 |
| | Both fresh and marine waters | 5.5 | 4.0 | Oct 1 to May 31 |
| Ammonia Nitrogen | No numeric criteria; narrative statement for prevention of toxicity. EPA water quality criteria for ammonia nitrogen toxicity used for TMDL. | pH dependent | | year round |
| Nitrate Nitrogen | Maximum contaminant level for public drinking water systems. | 10 mg/L as N | | year round |

To meet the designated uses of the Appoquinimink River and its tributaries, water quality targets, or *endpoints*, must be met under all conditions. The selection of these endpoints considers the water quality standards prescribed by those designated uses (Section 1.3). Results of the analysis of water quality data collected by DNREC in the basin indicate that the water quality criteria for both the minimum DO and average DO, which EPA interprets as a daily average concentration,  were not protected at a number of stations in the tidal Appoquinimink River.

These TMDLs have identified the pollutants and sources of pollutants that cause or contribute to the impairment of the DO criteria and allocate appropriate loadings to the various sources.  Given our scientific knowledge regarding the interrelationship of nutrients, biochemical oxygen demand (BOD), and SOD and their impact on DO, it is necessary and appropriate to establish numeric targets for TN, TP, and CBOD based on applicable state criteria to support the attainment of the numeric DO criteria. Establishing numeric water quality endpoints or goals also provides the ability to measure progress toward attainment of the water quality criteria and to identify the amount or degree of deviation from the allowable pollutant load.

While the ultimate endpoint for this TMDL was to ensure that the water quality criteria for DO was maintained throughout the Appoquinimink River basin, it was necessary to determine if other applicable water quality criteria were met and maintained.  Specifically, this applies to the numeric water quality criteria for nitrate nitrogen of 10 mg/L as N.  The water quality standard for nitrate nitrogen was protected throughout the Appoquinimink River basin.  Delaware does not have a numeric water quality criteria for ammonia nitrogen, however, the analysis indicates that ammonia nitrogen concentrations throughout the Appoquinimink River basin are consistent with the recommended EPA water quality criterion from Section 304(a) of the CWA.

Achieving these instream numeric water quality targets will ensure that the designated uses (aquatic life and human health) of waters in the Appoquinimink River basin are supported during critical conditions.

# 4.0 TMDL Methodology and Calculation

The following sections discuss the methodology used for TMDL development and results in terms of TMDLs and required load reductions for each stream segment listed on Delaware's 303(d) list as impaired due to nutrients. The selected methodology considers specific impacts and conditions determined necessary for accurate source representation and system response.

## 4.1 Methodology

Analysis of water quality data indicate that the Appoquinimink River is most susceptible to DO and aquatic life use impairments during the summer. More specifically, impairments occur during the summer as a result of multiple factors, including: SOD levels (impacted by land-based point and nonpoint source contributions), hydrodynamics (tidal influences), and oxygen's solubility based on temperature. To fully evaluate these factors and determine a TMDL for Appoquinimink River, a dynamic hydrodynamic and water quality model was utilized that included chemical and biological processes associated with nutrient enriched and eutrophic systems. An enhanced version of EPA's Water Quality Analysis and Simulation Program (WASP) model (Ambrose et al., 1993) which incorporated a predictive sediment diagenesis submodel was used for this TMDL analysis.

The computational framework for the Appoquiniminik River modeling effort included four components: (1) the Generalized Watershed Loading Functions (GWLF) watershed loading model, (2) the DYNHYD hydrodynamic model(WASP's hydrodynamic model), (3) the WASP water quality simulation model, and (4) the sediment diagenesis model. The inputs for the GWLF model, which are further described in Appendix A, included rainfall and land use data for subwatersheds representing the entire Appoquinimink River basin. Outputs from GWLF included flow rate, TN, and TP on a monthly basis. The outputs from GWLF were input to the DYNHYD and WASP models after conversion to daily values using rainfall data and a triangular hydrograph/pollutograph assumption. The DYNHYD and WASP models are based on an existing model developed and applied by DNREC (2001) for the Appoquinimink River (and described in Appendix B). Inputs for DYNHYD included river bathymetry, tidal forcing at the Delaware River boundary, and upstream inflows. Outputs from DYNHYD included tidal flows and water depths that were used by the WASP model to transport constituents throughout the Appoquinimink River system. The WASP model provides a generalized framework for simulating water quality and transport in surface waters and is based on a finite-segment approach. WASP is supported by the EPA's Center for Exposure and Assessment Modeling (CEAM) in Athens, Georgia. A more detailed description of the DYNHYD and WASP models can be found in Appendix B.

For this TMDL, several major updates have been implemented into the Appoquinimink water quality modeling framework previously developed by DNREC (2001). The major modifications to the modeling framework and system configuration are summarized in the following subsections.

### 4.1.1 Corrected Sediment-Water Column Connection

In the previous version of the Appoquinimink River model, the sediment compartment was isolated from the water column, resulting in no flux of nutrients from the sediment bed to the water column. Therefore, nutrients in the sediment were not affecting the DO concentrations in the water column in the previous model. This previous version of the WASP code was adequate when the model configuration did not include an active sediment layer. However, when an active sediment layer was included in the model, there was a lack of nutrient benthic fluxes because the original code was not written for an active sediment layer. This issue was resolved in the current effort by modifying the source code. The nutrient concentration in the water column is now responsive to the specified sediment nutrient flux. In the current model the in-stream sediment is a source of nutrients to the water column and does impact the DO concentrations.

### 4.1.2 Corrected Inconsistent CBODu/CBOD5 Ratio and Kd Values

In the previous version of the model, the carbonaceous biochemical oxygen demand (CBOD) deoxygenation rate (Kd) was set to 0.075/day, which corresponds to a CBODu/CBOD5 ratio of 3.19. However, in the boundary condition section, the CBODu/CBOD5 ratio was set as 1.58, which corresponds to a Kd decay rate of 0.2/day. This inconsistency was resolved through the recent calibration process, by using a Kd value of 0.10/day resulting in a corresponding CBODu/CBOD5 ratio of 2.54. By inputting the Kd value into the equation below, the CBODu/CBOD5 ratio can be determined. Assuming the instream CBOD deoxygenation rate (Kd) is a direct reflection of the wastewater characteristics (a reasonable assumption for highly treated effluents), the CBODu/CBOD5 ratio is related to Kd in the receiving water according to the following equation (Lung, 1998):

$$\frac{CBOD_u}{CBOD_5} = \frac{1}{1 - e^{-5Kd}}$$

and solving the above equation for Kd results in the following:

$$Kd = -\frac{\ln\left(1 - \frac{CBOD_5}{CBOD_u}\right)}{5}$$

### 4.1.3 Incorporated a Gaussian Temperature Function for Algal Growth Rate

In the standard WASP model, the temperature effect on algal growth rate is represented as a power function, which implies that a higher temperature results in a higher algal growth rate. This simplified assumption may not represent the conditions in many natural waterbodies. According to the observed data, the chlorophyll-*a* concentrations in the Appoquinimink River are relatively low in summer when temperature is high and the concentrations are significantly higher during fall when the temperature is lower. At the same time, there is no other evidence showing that this trend was caused by other factors. Therefore, it was assumed that temperature might be a prime factor responsible for this trend. To better represent this trend, the Gaussian temperature function, which has been considered to be more representative of real algal growth rate characteristics and is used in EFDC and other models (Park et al., 1995; HydroQual, 2001), was incorporated into the WASP model. This more accurately simulates the observed conditions in the watershed.

The formulation of the Gaussian temperature function is:

$$F(t) = \exp(-KTG1\,[T-TM1]^2) \quad \text{when } T <= TM1$$
$$F(t) = \exp(-KTG2\,[TM2-T]^2) \quad \text{when } T >= TM2$$

where, F(t) is the temperature correction function
T is the water temperature
KTG1 and KTG2 are the temperature correction coefficients
TM1 and TM2 are the lower and upper temperature bounds for optimal algal growth

4.1.4 Incorporation of a Diurnal DO Simulation Function Based on Phytoplankton Dynamics

Primary producers, such as phytoplankton, use nutrients during sun light hours for production and consume oxygen during nightfall when photosynthesis ceases. As a result these organisms can inflate DO concentrations during the day and lower DO concentrations through the night. As shown by the monitoring data, phytoplankton concentration can reach very high values in certain sections of the Appoquinimink River. It was therefore, necessary to include the impacts of primary production in the model. To account for the possible impact of the phytoplankton concentrations on DO, a diurnal DO simulation function was incorporated into the WASP framework. In addition, a simplified diurnal simulation module was added to the code to allow for a more accurate representation of DO fluctuation in the receiving water. In this simplified diurnal simulation module, the growth of phytoplankton occur during daylight hours and halt at night. The average solar radiation intensity was used to govern the algal dynamics during daylight hours, and a zero solar radiation intensity was used to restrict algal growth at night. The modified model is now capable of simulating time-variable DO with hourly resolution (or higher resolution as necessary), and estimating daily average, minimum, and maximum DO concentrations. To use the simplified diurnal simulation function, the light switch LGHTS were set to 6.0 to activate the relevant calculations. This addition to the model should better represent observed conditions.

#### 4.1.5 Incorporation of a Predictive Sediment Diagenesis Module

The previous modeling report by DNREC (2001) indicated that sediment nutrient fluxes play a major role in the Appoquinimink's DO impairments. It also recommended that a dynamic sediment flux model be incorporated to properly balance watershed contributions throughout the year and fluxes to and from the sediment. To better account for the relationship between SOD and external load, a sediment diagenesis model was incorporated into WASP for this project and is based on the sediment flux modeling theory of DiToro (2001), as well as an implementation by Lung (2000). The sediment diagenesis model takes into account the CBOD and nutrients moving between the sediment and water column. The sediment layers allow an interaction between the sediment oxygen demand and the water column. The model also describes changes in aqueous methane, gaseous methane, ammonia, and gaseous nitrogen. This is accomplished by maintenance of the mass balance of CBOD and organic nitrogen.

#### 4.1.6 Model Calibration and Validation

For WASP (and DYNHYD) modeling purposes, the Appoquinimink River system was divided into 47 segments from its confluence with the Delaware River to the headwaters of Drawyer Creek, Deep Creek, and Wiggins Mill Pond Branch (refer to Appendix B for more detailed information). Three small lakes or ponds were also included in the modeling framework (Shallcross Lake, Silver Lake, and Noxontown Pond). The DYNHYD and WASP modeling components were calibrated to flow and water quality conditions for the period May to July 1991. The model was validated using the period August to October 1991. The model calibration process involved modeling parameter adjustment, however the validation process simply involved application of the calibrated model parameters (without further adjustment). This calibration and validation approach enabled the dynamic sediment diagenesis model to generate results for the calibration period, which could then be used as a starting point for the validation condition. The DYNHYD model was run on a 5 second timestep and the WASP model was run on a 60 second timestep.

WASP model boundary conditions for the calibration and validation periods were generated using the GWLF watershed model (Appendix A), which was configured with meteorological data from the Wilmington New Castle County Airport and the 1992 MRLC landuse data. GWLF was run for the three-year period 1989 through 1991 using rainfall records from the airport. Flow and nutrient loads (TN and TP) were generated for subwatersheds used to represent the Appoquinimink watershed in GWLF and applied directly to respective WASP modeling segments for this entire time period. Although the WASP calibration and validation focused on 1991, it was necessary to simulate the two previous years, in order to stabilize the sediment diagenesis model. That is, rather than selecting arbitrary starting points for sediment-flux parameters, the model was run using predicted nutrient loads from the watershed over time to internally generate the sediment-flux parameters for the calibration condition.

The GWLF model generated TN and TP loads for delivery to the receiving waters in the watershed. These loads were, in turn, converted to nitrate-nitrite (NO2/NO3), ammonium (NH4), organic nitrogen, orthophosphate (OPO4), and organic phosphorus loads using ratios of: 0.670, 0.066, 0.264, 0.400, and 0.600, respectively. These ratios are consistent with those utilized in the 2001 DNREC analysis and were based on monitoring data. For application of these loads to the WASP model, the organic nutrient loads were additionally converted to CBOD loads. The following ratio was used: CBODu/organic nitrogen = 30.4. This ratio was initially determined based on the Redfield Ratio of 0.176 nitrogen(N)/carbon(C), and a carbon to oxygen ratio of 2.67 g O2/g C. This ratio was then refined for the waterbodies being evaluated through an iterative model calibration process. The relatively high CBODu/organic nitrogen ratio can be justified by the fact that in the watershed, organic nitrogen is relatively diminished (at low levels), corresponding to a higher C/N ratio (and CBODu/Org-N ratio).

For the calibration and validation periods a number of important assumptions were made regarding the boundary conditions from the Delaware River and the load being contributed by the MOT WWTP. Tidal contributions from the Delaware River varied depending on the time of year and were assumed to contribute 0.60 to 1.34 mg/L of NO2/NO3, 0.05 to 0.14 mg/L of NH3, 0.03 to 0.05 mg/L of OPO4, and 6.325 mg/L of CBODu. The MOT WWTP was assumed to contribute at levels based on 1991 discharge conditions. These conditions were used in the DNREC 2001 analysis and are as follows: 0.5 mgd, 0.0 mg/L of NO2/NO3, 10.0 mg/L of NH3, 0.845 mg/L of OPO4, and 19.5 mg/L of CBOD5 (55.4 mg/L of CBODu). This was done for the calibration and validation of the model since the calibration was to 1991 water quality data. However, the River was modeled with more current MOT data for the TMDL scenarios. In the various TMDL scenarios the pollutant and DO concentrations in the effluent were altered.

The calibration and validation plots for DO, chlorophyll-a, and nutrients (NH4, NO3, PO4, organic nitrogen, and organic phosphorus) are presented in Appendix C for the Appoquinimink River. Due to monitoring data limitations regarding time-variability, the plots present longitudinal profiles for the river (from the Delaware River to upstream of Wiggins Mill Pond) of minimum, mean, and maximum daily values of the constituents (over the calibration period and validation period separately). The model results are compared to mean, minimum, and maximum monitoring values at different locations for the calibration and validation periods (separately). It should be noted that the model results are reflective of predictions for every day during the calibration period (May through July) and validation period (August through October) while the monitoring data are only reflective of a few days during that period.

The goal of calibration and validation was to most accurately represent the observed range of constituent variability at all locations along the river's length.

## 4.2 TMDL Calculation

TMDLs were established for each individual segment listed on Delaware's 303(d) list. TMDLs consist of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). The TMDLs identify the sources of pollutants that cause or contribute to the impairment of the DO criteria and allocate appropriate loadings to the various sources. Given the scientific knowledge available, and utilizing the model processes that describe the interrelationship of nutrients, CBOD, SOD, and their impact on DO, it was determined necessary to prescribe WLAs and LAs for TN and TP (for land-based contributions) and CBOD, TP, and TKN (for the MOT WWTP).

The equation used for TMDLs and allocations to sources is:

$$TMDL = \sum WLA + \sum LA + MOS$$

The WLA portion of this equation is the total loading assigned to point sources. Federal regulations (40 CFR 130.7) require TMDLs to include individual WLAs for each point source. The LA portion is the loading assigned to nonpoint sources. According to federal regulations (40 CFR 130.2(g)), load allocations are best estimates of the nonpoint or background loading. These allocations may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint sources should be distinguished (EPA, 2001). The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis.

For this study, the MOS is assumed implicit through conservative assumptions used in the modeling process. These conservative assumptions include:

- There is a MOS with respect to the 4.0 mg/L minimum DO standard. That is, the TMDL conditions bring the minimum DO well above the required minimum of 4.0 mg/L while simultaneously closely meeting the 5.5 mg/L average.
- Losses of land-based nutrient and organics loads for the storms along the path to the receiving waters were not explicitly represented in the model.
- The model does not consider loss of organic matter from the sediment due to high flow conditions. Therefore, all organics that settle remain available for diagenesis processes. Thus, the predicted SOD may be somewhat higher than that in reality.

While the model achieves a reasonable level of accuracy, there is a certain amount of uncertainty associated with the model predictions. This uncertainty can be attributed to a number of factors, including:

- There are limited spatially and temporally representative water quality data.
- In generating boundary condition loads to the stream segments, it was assumed that long-term meteorological data for the Wilmington Airport is representative of conditions throughout the Appoquinimink watershed.
- The GWLF model does not explicitly simulate detailed nutrient generation and loading processes although it does provide reasonable trends.
- GWLF generates monthly nutrient load and flow, while the receiving water quality model requires higher temporal resolution to account for the time variability in water quality. The monthly load was distributed to daily values based on the rainfall distribution.
- GWLF only generates loads for TN and TP, while WASP requires loads for NH3, NO3/NO2, OPO4, CBOD, organic nitrogen, and organic phosphorus. Therefore, the TN and TP generated by the GWLF model were partitioned into the constituents used in WASP model based on the ratio previously used in 1998 TMDL and DNREC's recent modeling analysis.
- The receiving water quality model is a simplified representation of reality. It uses discrete computational segments to represent a continuous system, uses a lumped chlorophyll-a parameter to represent the entire population of algae, uses CBOD parameter CBOD to represent organic carbon, and does not explicitly account for the impact of groundwater (although groundwater contributions are represented in the GWLF model).
- Water quality monitoring data focused on evaluating the specific impacts of the tidal marshes were not available to support this study. As such, detailed processes associated with the marshes were not explicitly represented in the receiving water modeling framework (DYNHYD and WASP). Landuse data were available for the watershed, and thus the wetland areas (marshes) were represented as a distinct landuse category in the GWLF modeling framework. Because insufficient monitoring data were available to fully define the impact (in terms of a net gain or loss) of the wetlands, neither the detainment capacity nor loading processes were explicitly considered. That is, land-based constituent loads from the watershed, which in a good portion of the Appoquinimink River watershed pass through wetlands prior to feeding into the rivers (and tributaries), were not considered to be detained (and thus utilized) by the wetlands. At the same time, contributions of nutrients and organic matter from the wetlands themselves were also not explicitly represented. It was assumed that these factors would have a balancing effect on the overall loading to the river. Because the model was successfully calibrated through a comparison of predictions with in-stream monitoring data and did not indicate a major contributing source was being overlooked, the representation was deemed appropriate for TMDL analysis.

The TMDL development process involved the following steps:

1. The calibrated and validated model was run for a “baseline” condition. This condition was essentially the starting point for TMDL analysis. For the baseline condition, the MOT WWTP was set at its current permit limits which were based on EPA’s 1998 Appoquinimink TMDL WLA (as identified in Table 2-2), the Delaware Bay contributions were assumed to be consistent with those identified in Section 4.1.6, and the 1992 landuse scenario was used as the basis for generating flow and nutrient loads from the watershed to the receiving water models (DYNHYD and WASP). Although the 2002 landuse data were acquired and evaluated, the 1992 landuse data were used in the TMDL analysis. Using the 1992 landuse data likely results in a slightly different “baseline” loading than for 2002, however, this has no implications on the WLA and LA allocations (and total TMDL). The TMDL represents the assimilative capacity of the river and thus does not change due to the landuse distribution of the contributing watershed. The meteorological conditions that occurred during 1991 were assumed representative of typical conditions in the watershed. As identified in Section 4.4, this year was typical of most observed in the watershed and covered a range of hydrologic conditions. Dissolved oxygen concentrations predicted by the model for the period June through September were compared directly to Delaware’s DO criteria.
2. In the event that DO levels were not at or above the criteria, nutrient load reductions were required. The load reduction process involved reducing nutrient loads (specifically TN and TP) from the watershed until the DO criteria were met at all locations on impaired waters in the Appoquinimink River watershed.

## 4.3 TMDL Results and Allocations

TMDLs were developed for the Appoquinimink watershed based on Delaware’s DO criteria for fresh waters. Specifically, the minimum of the daily average DO concentrations predicted by the model during the June-September period (at every point along the impaired segments) was required to be at or above 5.5 mg/L. Additionally, the minimum of the daily minimum concentrations predicted by the model during the same period (at every point along the impaired segments) was required to be at or above 4.0 mg/L. Modeling results for impaired segments that show compliance with these criteria are presented in Appendix D. Note that each plot contains “baseline” conditions as described above and the successful compliance scenario (for which the TMDL allocations were based).

TMDLs are presented in Table 4-1 for impaired segments of the Appoquinimink River watershed. The TMDLs are presented by subwatershed contributing to the impaired segments (Figure 4-1). The total TMDL for each impaired segment is the combination of all TMDLs for contributing subwatersheds and for the MOT point source (Table 4-2), where applicable. These watershed-based loads and the allocated load for the MOT WWTP enable the in-stream DO concentrations to meet criteria under all conditions. It should be noted that the WLAs for the storm water permits and the LAs for areas not covered by storm water permits have been combined into a single WLA for each subwatershed (and impaired segment) and have not been presented separately. DNREC and New Castle County are currently in the process of mapping storm water discharge locations that are covered by the permits, and as such insufficient data are currently available to justify a more detailed allocation to storm water permit. Once the mapping effort on behalf of DNREC and the county is complete, the TMDL can be updated to distribute the TMDL among the storm water permits (WLAs) and the nonpoint sources (LAs). The WLA is assigned to New Castle County, Delaware Department of Transportation, Middletown, Odessa, and Townsend Township. The TMDL calls for a 60% reduction in nutrient loadings to the Appoquinimink River. When the TMDL was run using current land use data, without the best management practices included, a 56% reduction in nutrient loadings w required.

The TMDL represents one allocation scenario. As implementation of the established TMDL proceeds, DNREC may find that the applicable water quality standard can be achieved through other combinations of point and nonpoint source allocations that are more feasible and/or cost effective. If that happens, DNREC is free to re-run the model to propose a revised TMDL with an alternative allocation scenario that will achieve water quality standards. It should be noted that, by transferring loadings from one source to another, the results of the model may change even if the total loading remains the same because the proximity and timing of difference sources impacts the river differently.

**Table 4-1.** TMDLs and baseline loads by contributing subwatershed for impaired waters of the Appoquinimink.

| Segment Name | Segment ID | Contributing Subwatershed(s) | Baseline TN (lbs/yr) | Baseline TP (lbs/yr) | WLA TN (lbs/yr) | WLA TP (lbs/yr) | % Reduced TN (lbs/yr) | % Reduced TP (lbs/yr) |
|---|---|---|---|---|---|---|---|---|
| Appoquinimink River (Lower) | DE010-001-01 | 1 | 35,185 | 4,267 | 14,074 | 1,707 | 60% | 60% |
| | | 2 | 16,842 | 2,240 | 6,737 | 896 | 60% | 60% |
| | | 3 | 3,866 | 579 | 1,547 | 231 | 60% | 60% |
| | | 4 | 17,689 | 2,156 | 7,075 | 862 | 60% | 60% |
| | | 5 | 18,471 | 2,560 | 7,388 | 1,024 | 60% | 60% |
| | | 6 | 13,746 | 1,854 | 5,498 | 742 | 60% | 60% |
| | | 7 | 17,386 | 2,184 | 6,954 | 874 | 60% | 60% |
| | | 8 | 26,486 | 3,418 | 10,594 | 1,367 | 60% | 60% |
| | | 9 | 13,416 | 1,734 | 5,366 | 693 | 60% | 60% |
| | | 10 | 22,035 | 3,074 | 8,814 | 1,230 | 60% | 60% |
| | | The total TMDL for this segment also includes the WLAs for the MOT WWTP presented in Table 4-2. | | | | | | |
| Appoquinimink River (Upper) | DE010-001-02 | 2 | 16,842 | 2,240 | 6,737 | 896 | 60% | 60% |
| | | 5 | 18,471 | 2,560 | 7,388 | 1,024 | 60% | 60% |
| | | 6 | 13,746 | 1,854 | 5,498 | 742 | 60% | 60% |
| | | 7 | 17,386 | 2,184 | 6,954 | 874 | 60% | 60% |
| | | 8 | 26,486 | 3,418 | 10,594 | 1,367 | 60% | 60% |
| | | The total TMDL for this segment also includes the WLAs for the MOT WWTP presented in Table 4-2. | | | | | | |
| Drawyer Creek | DE010-001-03 | 1 | 35,185 | 4,267 | 14,074 | 1,707 | 60% | 60% |
| | | 9 | 13,416 | 1,734 | 5,366 | 693 | 60% | 60% |
| | | 10 | 22,035 | 3,074 | 8,814 | 1,230 | 60% | 60% |
| Wiggins Mill Pond to confluence with Noxontown Pond | DE010-002-01 | 5 | 18,471 | 2,560 | 7,388 | 1,024 | 60% | 60% |
| Deep Creek to confluence with Silver Lake | DE010-002-02 | 7 | 17,386 | 2,184 | 6,954 | 874 | 60% | 60% |
| Noxontown Pond | DE010-L01 | 5 | 18,471 | 2,560 | 7,388 | 1,024 | 60% | 60% |
| | | 6 | 13,746 | 1,854 | 5,498 | 742 | 60% | 60% |
| Silver Lake | DE010-L02 | 7 | 17,386 | 2,184 | 6,954 | 874 | 60% | 60% |
| | | 8 | 26,486 | 3,418 | 10,594 | 1,367 | 60% | 60% |
| Shallcross Lake | DE010-L03 | 10 | 22,035 | 3,074 | 8,814 | 1,230 | 60% | 60% |

**Table 4-2.** WLAs for the MOT WWTP NPDES discharge (DE0050547).

| Parameter | Permit Value | WLA | % Reduced |
|---|---|---|---|
| Flow | 0.5 mgd | 0.5 mgd | 0% |
| CBOD-5 day | 34.8 lbs/day | 34.8 lbs/day (12,702 lbs/year) | 0% |
| Total Kjeldahl Nitrogen (TKN) | 3,796 lbs/year | 10.4 lbs/day (3,796 lbs/year) | 0% |
| Total Phosphorus (TP) | 2.1 lbs/day | 2.1 lbs/day (766.5 lbs/year) | 0% |

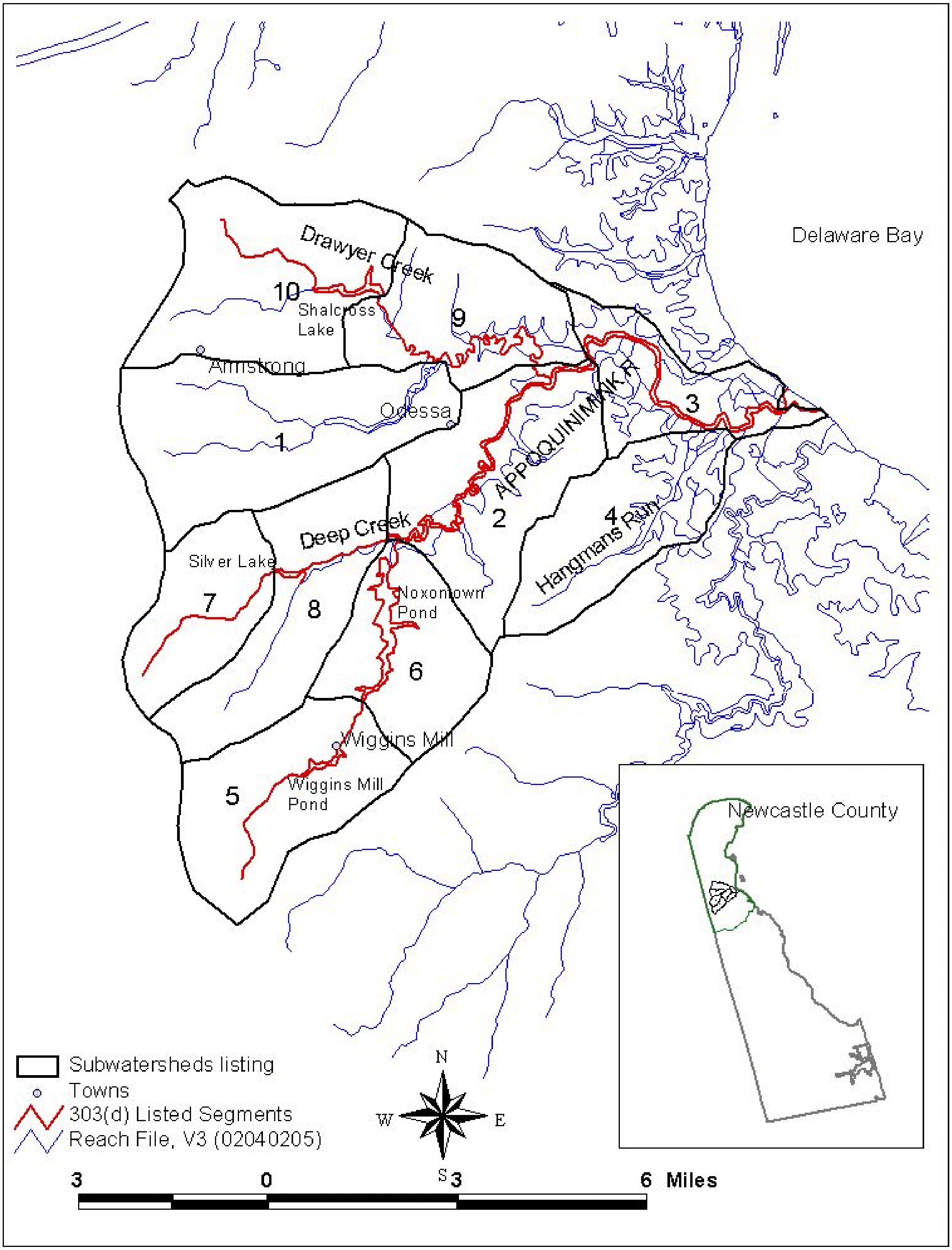


**Figure 4-1.** Map of Appoquinimink subwatersheds for summarizing TMDLs by impaired segment.

## 4.4 Consideration of Critical Conditions

Federal Regulations (40 CFR 130.7(c)(1)) require TMDLs to consider critical conditions for streamflow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality in waterbodies are protected during periods when they are most vulnerable. Critical conditions include combinations of environmental factors that result in attaining and maintaining the water quality criteria and have an acceptably low frequency of occurrence (USEPA, 2001).

TMDLs for the Appoquinimink River adequately address critical conditions through modeling for an entire year and using 1991 meteorological data, specifically. All conditions were considered through modeling for a full year, including the critical summer period when DO impairment is prevalent in the watershed. Because the receiving water model makes predictions at a sub-hourly timestep for the entire modeling period, it predicts constituent levels for low-flow as well as for storm events. More importantly, the model makes predictions for critical conditions overlooked by a steady-state analysis such as 7Q10 (e.g., by simulating relatively low-flow conditions that follow a storm event). A steady-state low-flow analysis assumes minimal land-based loading inputs, however, these inputs (which are typically contributed during storm events) become the most critical factor even during low flow events. Thus, the current modeling framework can be used to evaluate critical periods in more detail than a steady-state 7Q10 evaluation. The year 1991 was selected for modeling based on an analysis of available data. A statistical analysis was performed on USGS flow data in Morgan Creek (which was used as the reference watershed for the GWLF modeling effort and is assumed to be representative of conditions in the Appoquinimink watershed) since no data were available for the Appoquinimink River. The intention of the analysis was to compare annual volume totals at the gaging station for 1991 and the period 1980 through 2000. It is apparent from Figure 4-2 that the total volume for 1991 is very close to the long-term average annual volume.

In addition to the annual volumetric analysis, flow-duration curves for 1991 and the period 1980 through 2000 were compared. Figure 4-3 suggests that 1991 was representative of most flow conditions observed at the gage over a longer period of time, with the exception of extreme flood events and droughts. While the hydrologic regime of 1991 was consistent with average conditions throughout the past two decades, it also showed extreme depressions of dissolved oxygen in the monitoring data. This combination of factors suggested that 1991 meteorological conditions would be most representative and protective of conditions in the Appoquinimink River watershed.

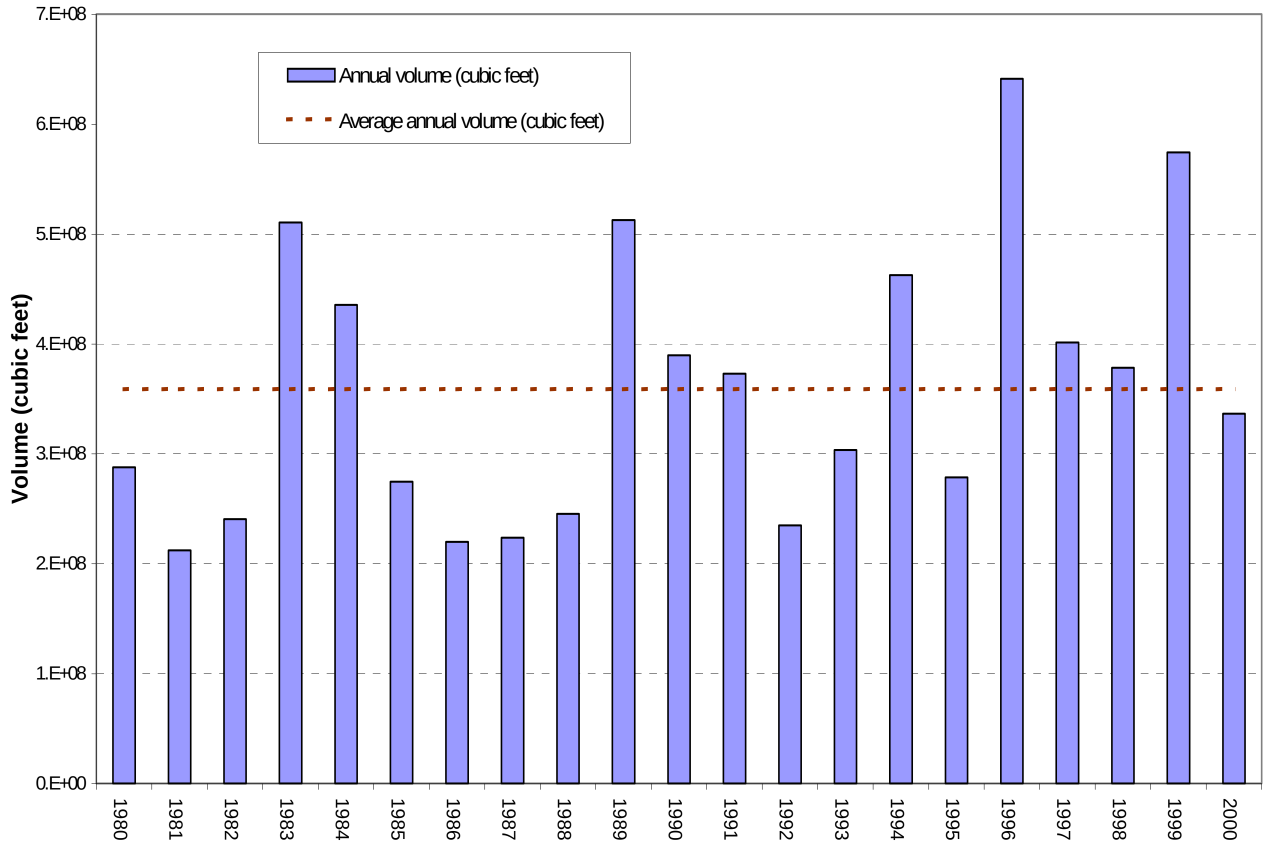


**Figure 4-2.** Volumetric analysis at the Morgan Creek USGS gage

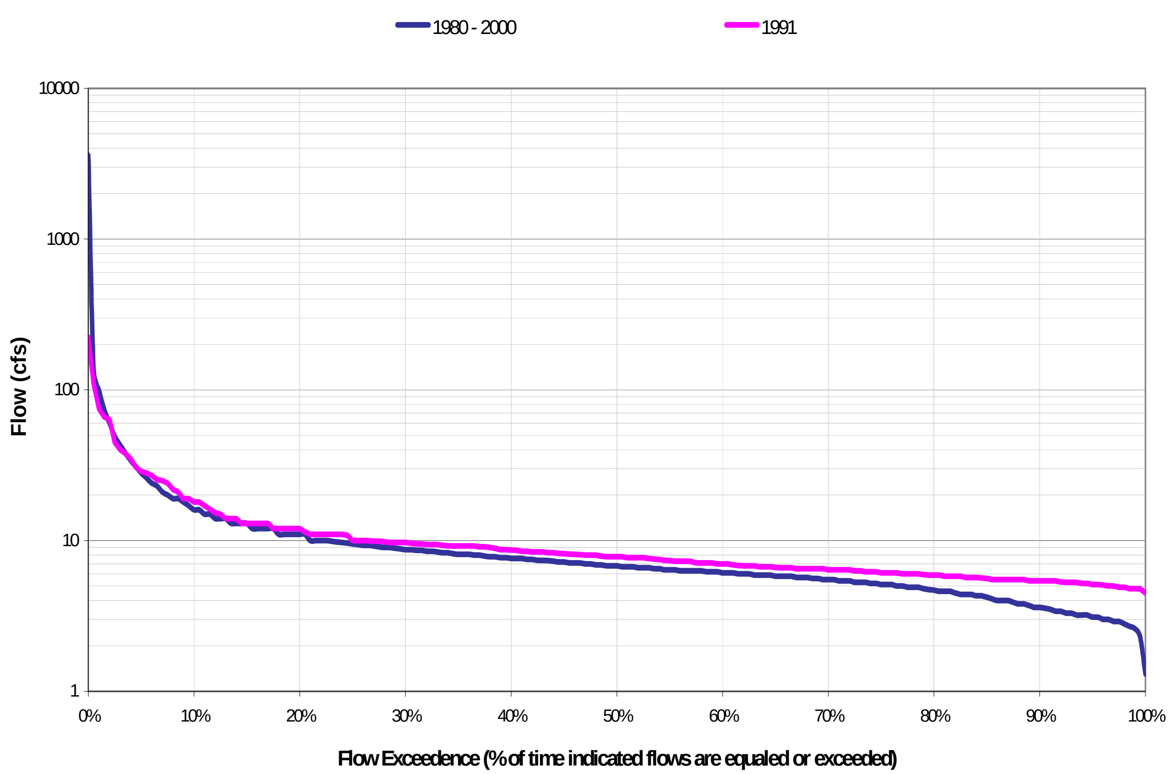


**Figure 4-3.** Flow-exceedance curve for the USGS gage on Morgan Creek

## 4.5 Consideration of Seasonal Variation

TMDLs for the Appoquinimink River adequately address seasonal variation directly through time-variable watershed and receiving water modeling. The linked modeling system simulates rainfall-runoff processes for the watershed throughout the year (for all seasons) as well as in-stream response. This approach provided insight into the time-variable nature of watershed loading and sediment diagenesis on DO levels in the Appoquinimink River and its tributaries. Rather than considering a single, extreme condition, this approach was comprehensive and represented a full seasonal analysis.

# 5.0 Reasonable Assurance and Implementation

Reasonable assurance indicates a high degree of confidence that each WLA and load allocation in a TMDL will be implemented. EPA expects the state to implement these TMDLs by ensuring that NPDES permit limits are consistent with the WLAs described herein. According to 40 CFR 122.44(d)(1)(vii)(B), the effluent limitations for a NPDES permit must be consistent with the assumptions and requirements of any available WLA for the discharge prepared by the state and approved by EPA. Furthermore, EPA has the authority to object to issuance of a NPDES permit that is inconsistent with the WLAs established for that point source. Additionally, according to 40 CFR 130.7(d)(2), approved TMDL loadings shall be incorporated into the state's current water quality management plans. These plans are used to direct implementation and draw upon the water quality assessments to identify priority point and nonpoint source water quality problems, consider alternative solutions, and recommend control measures. This provides further assurance that the pollutant allocations of the TMDLs will be implemented in the Appoquinimink River basin.

Development of TMDLs is only the beginning of the process for stream restoration and watershed management. Load allocations to point and nonpoint sources serve as targets for improvement, but success is determined by the level of effort put forth in making sure that those goals are achieved. Load reductions proposed by nutrient and dissolved oxygen TMDLs require specific watershed management measures to ensure successful implementation.

In terms of nonpoint sources, the load allocations are representative of expected pollutant loads during critical conditions from baseflow, atmospheric deposition, and traditional land-based sources. The analysis was performed using early 1990's landuse data and thus the baseline loads from the watershed are representative of conditions in the watershed at that time. The Appoquinimink River watershed has undergone significant change since the early 1990's. Many of the agricultural lands have been urbanized and a number of best management practices (BMPs) have been implemented. Based on the assumption that nutrient loadings are generally higher for agricultural areas than urban areas and that the BMPs are achieving nutrient load reductions, it is likely that current watershed nutrient loadings are less than those presented in the baseline condition. The BMP data was not sufficient to model in this TMDL. EPA expects that a portion of the reductions called for in the TMDL have already been achieved with these BMPs. A summary of current BMPs in the Appoquinimink River watershed and estimates of their corresponding load reductions are provided in Table 5-1 (based on personal communication with DNREC, November 2003).

Further implementation of BMPs in conjunction with waste load reductions from point sources should achieve the loading reduction goals established in the TMDLs. Further ground truthing will be performed to assess both the extent of existing BMPs, and to determine the most cost-effective and

**Table 5-1.** Summary of Current BMPs in the Appoquinimink River watershed and corresponding estimated nutrient load reductions (source: DNREC, 2003)

environmentally protective combination of BMPs required for meeting the nutrient reductions outlined in this report.

| Category | System/acreage | Estimated TN reduction lbs/day | Estimated TP reduction lbs/day |
|---|---|---|---|
| **Onsite Wastewater Disposal Systems** | | | |
| Holding tank compliance | 0 | | |
| Pump-out | 459 | 2.5 | 1.0 |
| Alternative systems | | | |
| *Subtotal* | | *2.5* | *1.0* |
| **Agriculture** | | | |
| Nutrient relocation & alternative use | | | |
| Grassed waterways | 2.5 | 0.26 | 0.01 |
| Filter Strips | 18 | 1.87 | 0.05 |
| Riparian Buffers | | | |
| Grass Buffers | 4.8 | 0.5 | 0.01 |
| Forest Buffers | | | |
| Ponds | 4 | 0.14 | 0 |
| Wetlands | 83 | 5.68 | 0.14 |
| Grass Filter strips | 14 | 0.58 | 0.01 |
| Wildlife Habitat | 14 | 0.58 | 0.01 |
| Cover Crops | 992 | 42.81 | 0.08 |
| *Subtotal* | | *52.81* | *0.30* |
| **Stormwater** | | | |
| Dry Infiltration Trench | 0.3 | 0.00 | 0.00 |
| Extended Detention Ponds | 5 | 0.03 | 0.02 |
| Filter Strips | 3 | 0.1 | 0.00 |
| Grass Swales | 1.5 | 0.00 | 0.00 |
| Retention wet ponds | 21 | 0.31 | 0.14 |
| Wet Ponds | 16 | *0.23* | 0.11 |
| Dry Ponds | 2.1 | *0.00* | 0.00 |
| Stormwater wetland | 11.5 | 0.17 | 0.09 |
| Wet In-Filter System | 7.5 | 0.02 | 0.02 |
| Infiltration systems | 0.5 | 0.01 | 0.00 |
| *Subtotal* | | *0.87* | *0.38* |
| **TOTAL** | | **56.18** | **1.68** |
| TMDL required reduction based on Model Baseline results | | **304.3** | **39.6** |
| Estimated Progress Towards TMDL | | **18.5%** | **4.2%** |

To provide additional assurance that TMDLs are protective of the designated uses of the Appoquinimink River watershed, analysis was performed to ensure that WLAs for ammonia did not result in violations of water quality criteria. Delaware does not have a water quality standard for ammonia nitrogen, so the EPA national criterion for ammonia in fresh water was used (USEPA, 1998). The criteria maximum concentration (CMC or acute criteria) and criteria continuous concentration (CCC or chronic criteria) ammonia standards are calculated based on pH. The water quality sample data in the STORET database were used to calculate the mean, 75th percentile, and 90th percentile pH values for the Appoquinimink River watershed using all data for all stations for the months of July and August during the period 1970 through 1998. The corresponding 4-day CCC, 30-day CCC, and 1-hour CMC ammonia nitrogen criteria are shown in Table 5-2. The recent STORET data from 1990 to 1998 indicate the highest ammonia nitrogen concentration was 0.681 mg/L as N which is below the criteria listed in Table 5-2. Therefore, since the TMDL allocations will reduce the loading of ammonia from existing conditions, the ammonia toxicity criteria are expected to be protected within the Appoquinimink River basin.

**Table 5-2. Ammonia nitrogen criteria for Appoquinimink River basin.**

| Statistic | pH (S.U.) Jul-Aug | Ammonia Nitrogen Criteria (mg/L as N) | | | |
|---|---|---|---|---|---|
| | | 30-day CCC | 4-day CCC | 1-hour CMC (salmonids present) | 1-hour CMC (salmonids absent) |
| mean | 7.52 | 2.238 | 4.476 | 12.89 | 19.30 |
| 75th percentile | 7.80 | 1.661 | 3.322 | 8.11 | 12.14 |
| 90th percentile | 8.35 | 0.732 | 1.464 | 2.86 | 4.28 |

The maximum concentration nitrite+nitrate nitrogen concentration reported in the STORET database for all stations in the Appoquinimink River basin is 6.57 mg/L as N. This is below the nitrate water quality standard of 10 mg/L as N, therefore, it is reasonable to expect the nitrate standard will be protected as a result of the TMDL allocations.

# 6.0 Public Participation

Public participation is a requirement of the TMDL process and is essential to its success. At a minimum, the public must be allowed at least 30 days to review and comment prior to establishing a TMDL. Also, EPA must provide a summary of all public comments and responses to those comments to indicate how the comments were considered in the final decision.

The draft of the *Nutrient and DO TMDL Development for Appoquinimink River, Delaware* was open for public comment from October 10, 2003 to November 18, 2003. On November 10, 2003, a public meeting was held in the Brick Mill Elementary School in Middletown, Delaware. The results of TMDL development were presented to the public at this meeting. Approximately 30 people attended the meeting. Comments received at the meeting were used in amending the TMDL to its final format.

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# Appendix A: GWLF Model

The objective of this Appendix is to describe the watershed modeling approach used to support TMDL development for the Appoquinimink River.

## GWLF Model

The watershed model for the Appoquinimink River watershed was developed using the GWLF model and the BasinSim 1.0 interface. The GWLF model, which was originally developed by Cornell University (Haith et al., 1992), provides the ability to simulate runoff, sediment, and nutrient loadings from watersheds given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. GWLF is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads based on daily water balance totals that are summed to give monthly values.

GWLF is an aggregate distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios. Each area is assumed to be homogeneous with respect to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but aggregates the loads from each area into a watershed total. In other words, there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for subsurface flow contributions. Daily water balances are computed for an unsaturated zone as well as for a saturated subsurface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (e.g., land cover/soil type combination). The KLSCP factors are variables used in the calculations to depict changes in soil loss/erosion (K), the length/slope factor (LS), the vegetation cover factor (C), and the conservation practices factor (P). A sediment delivery ratio based on watershed size and a transport capacity based on average daily runoff are applied to the calculated erosion to determine sediment yield for each source area. Surface nutrient losses are determined by applying dissolved nitrogen and phosphorus coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area. Manured areas, as well as septic systems, also can be considered. Urban nutrient inputs are all assumed to be solid phase, and the model uses an exponential accumulation and washoff function for these loadings. Subsurface losses are calculated using dissolved nitrogen and phosphorus coefficients for shallow groundwater contributions to stream nutrient loads, and the subsurface submodel considers only a single, lumped-parameter contributing area. Evapotranspiration is determined using daily weather data and a cover factor dependent on land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values. All the equations used by the model can be found in the original GWLF paper (Haith and Shoemaker, 1987) and GWLF User's Manual (Haith et al. 1992).

For execution, the model requires three separate input files containing transport, nutrient, and weather-related data. The transport file (TRANSPRT.DAT) defines the necessary parameters for each source area to be considered (e.g., area size, curve number) as well as global parameters (e.g., initial storage, sediment delivery ratio, streambank erosion coefficient ) that apply to all source areas. The nutrient file (NUTRIENT.DAT) specifies the various loading parameters for the different source areas identified (e.g., urban source area accumulation rates, manure concentrations). The weather file (WEATHER.DAT) contains daily average temperature and total precipitation values for each year simulated.

**Model Setup**

Watershed data needed to run the GWLF model were generated using GIS spatial coverages, streamflow data, local weather data, literature values, and other information. The Appoquinimink watershed was segmented into seven subwatersheds to represent nutrient loadings (Figure A-1). Three of the subwatersheds represent the three tributaries to Appoquinimink River, which are Drawyer Creek, Deep Creek and Hangman's Run. The tributary feeding into Drawyer Creek (Dove Nest Branch) was delineated to represent the loading coming from this subbasin into the Drawyer Creek sub-basin. The remaining three subbasins were delineated to represent the loadings alongside the Appoquinimink River. The impaired and reference subwatersheds were delineated based on USGS 7.5 minute digital topographic maps (24K RG - Digital Rastar Graphics), USGS Digital Elevation Model data, and the EPA RF3 stream coverage.

Nonpoint source pollution is rainfall driven, therefore precipitation data are necessary to drive the watershed model. Local rainfall and temperature data were used to simulate flow conditions in modeled watersheds. Daily precipitation and temperature data were obtained from local National Climatic Data Center (NCDC) weather stations. The weather data collected at the Wilmington New Castle County Airport NCDC station (precipitation data and temperature data) were used to construct the weather file used in modeling. This station is approximately 19 miles away from the Appoquinimink

River. It has complete coverage of data starting from 1948 until 2000 (99% coverage). Table A-1 shows the weather stations used in the watershed model.

**Table A-1.** Meteorological Stations

| Station ID | Station Name | Data Begin Date | Data End Date | Percent Coverage | Lat. | Long. | Elev. |
|---|---|---|---|---|---|---|---|
| DE 9595 | Willmington New Castle County Airport | 8/1/1948 | 12/31/2000 | 99 | 39.6728 | -75.60083 | 74 |
| DE 13781 | Willmington New Castle County Airport | 1/1/1948 | 12/24/2001 | 99 | 39.6728 | -75.60083 | 74 |

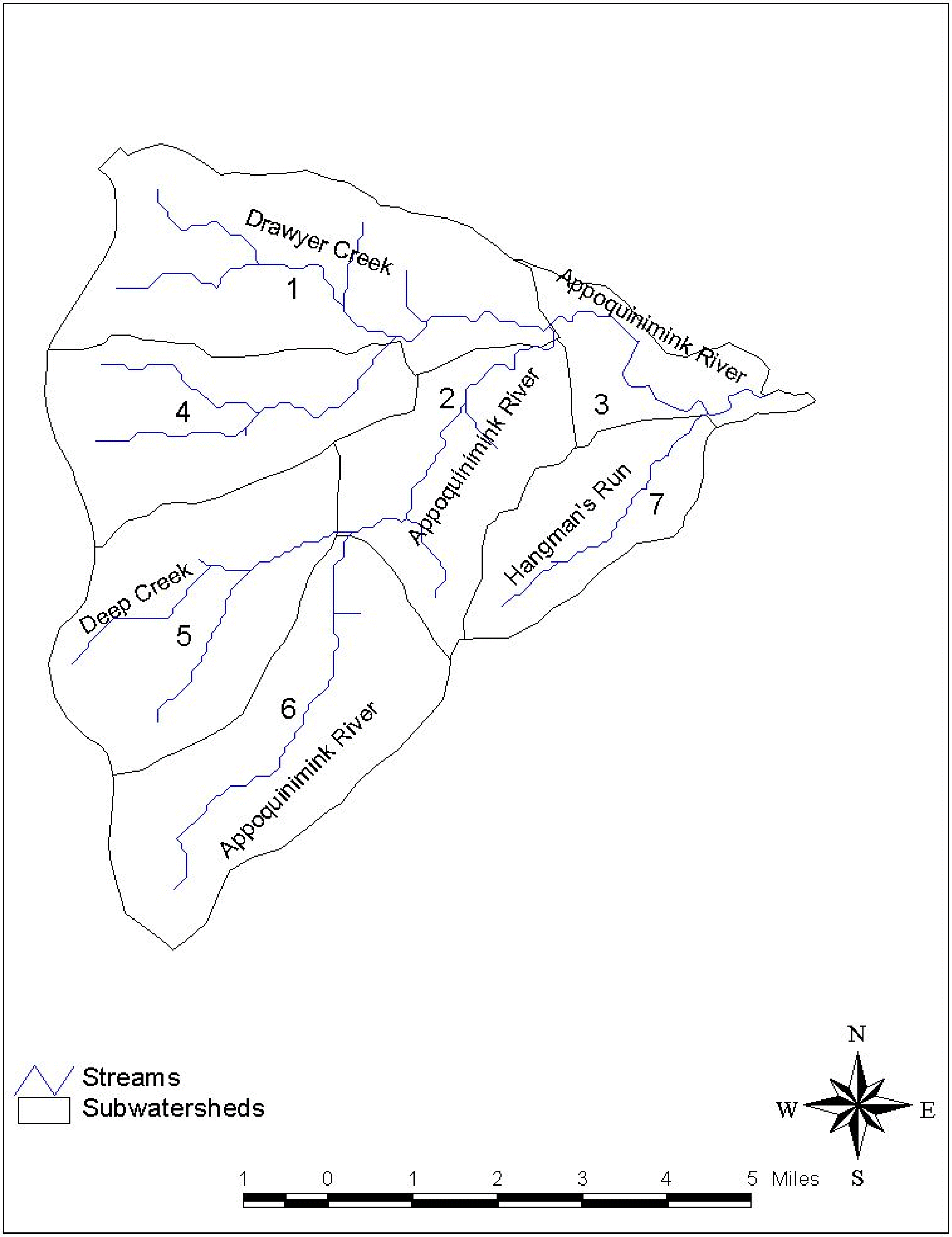



**Figure A-1.** Appoquinimink River subwatershed delineations.

**Model Testing**

Streamflow data are generally used to test or calibrate watershed hydrologic parameters for the GWLF model. There are no active U.S. Geological Survey (USGS) gages in the Appoquinimink River watershed, nor is there information available regarding historical stream flow data. Therefore a reference watershed, where data are available and which exhibits similar soil and landuse characteristics, was also modeled (drainage area to the USGS gage on Morgan Creek near Kennedyville, Maryland - Figure A-2). Once calibrated, the hydrology parameters from the reference watershed were applied to the Appoquinimink River watershed.

GWLF predicted overall water balances in the reference watershed. For the Morgan Creek watershed, weather data obtained from the NCDC meteorological station located at Willmington New Castle County Airport were used to model for a 10-year time period (1989 through 1999). The modeling period was selected based on the availability of weather and flow data that were collected during the same time period. It was assumed that a 10 year period would incorporate the seasonal variation in the model with a range of precipitation and stream flow conditions being represented.. Calibration plots for the entire 10-year period and for the 3-year period for which the river was modeled for the TMDL are presented in Figures A-3 and A-4. A total flow volume error percentage of less than 10 percent was achieved (4% error for the 10-year period and 1.5% error for the 3-year period). In general, the seasonal trends and peaks are captured reasonably well for the 10 year period in the reference watershed.

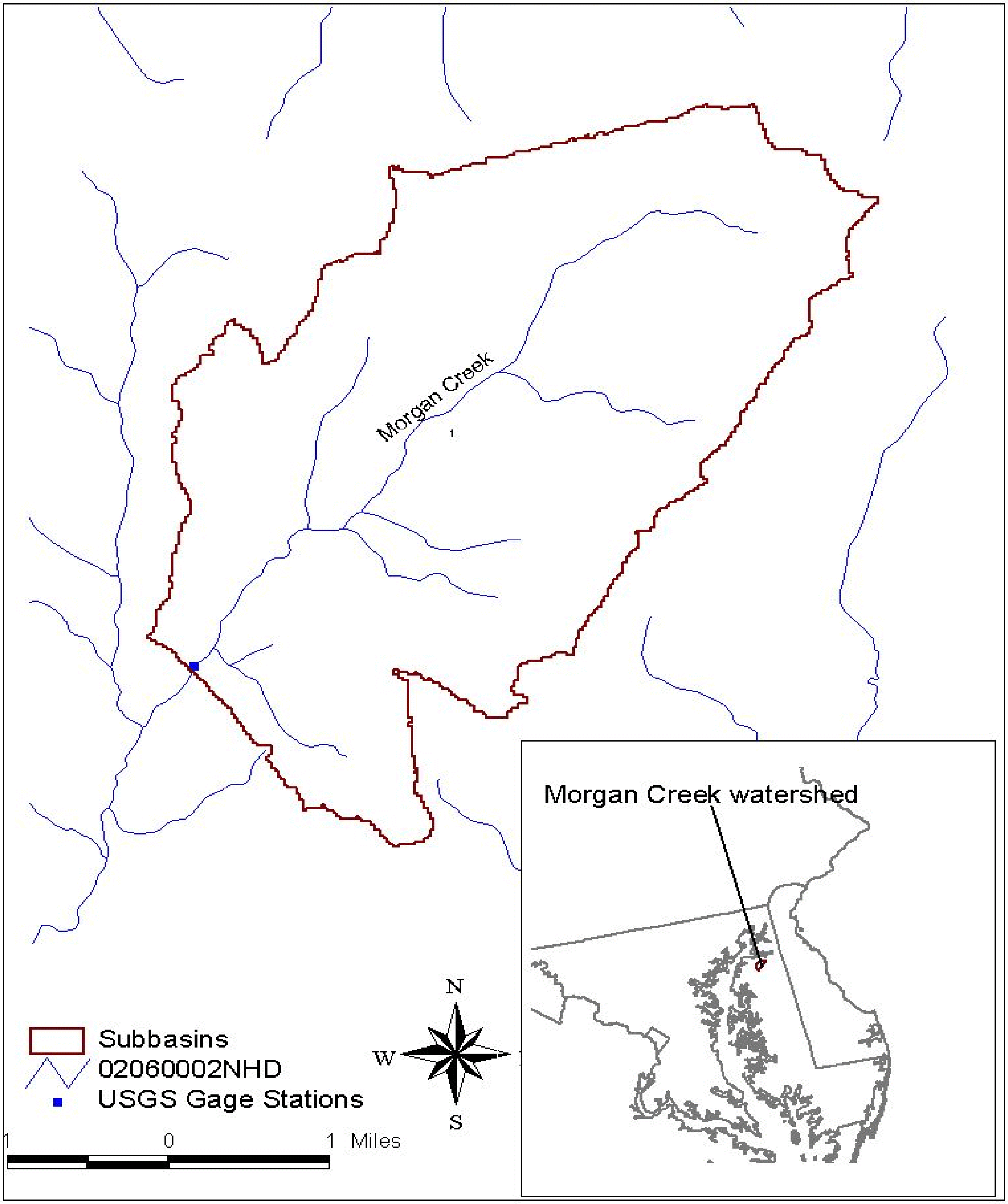



**Figure A-2**. Morgan Creek watershed

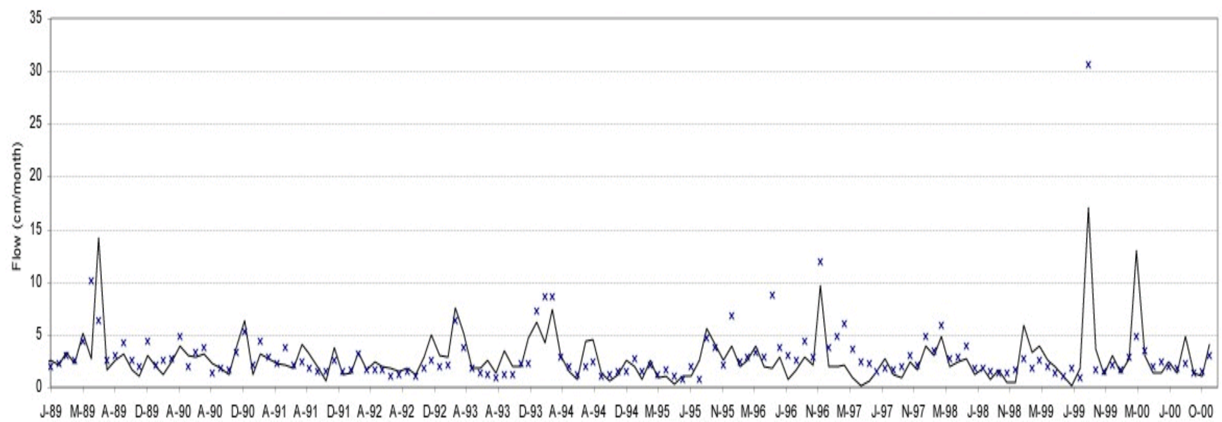



**Figure A-3.** Hydrology Calibration - Morgan Creek at USGS 01493500 (1/1/1989 - 12/31/1999)

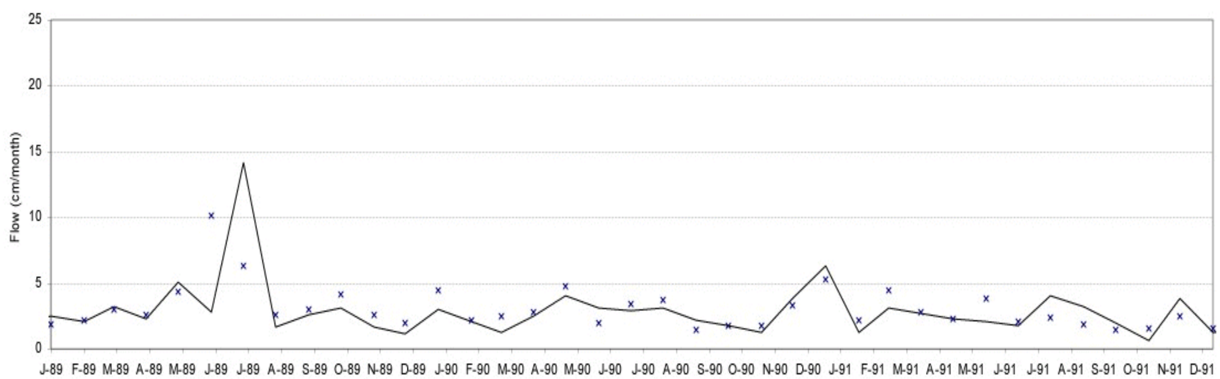



**Figure A-4.** Hydrology Calibration - Morgan Creek at USGS 01493500 (1/1/1989 - 12/31/1991)

## Explanation of Important Model Parameters

In the GWLF model, the nonpoint source load calculation is affected by terrain conditions, such as the amount of agricultural land, land slope, soil erodibility, farming practices used in the area, and by background concentrations of nutrients (nitrogen and phosphorus) in soil and groundwater. Various parameters are included in the model to account for these conditions and practices. Some of the more important parameters are summarized as follows:

*Areal extent of different land use/cover categories:* Land use information from the Multi-Resolution Land Characterization (MRLC) completed in 1992 was available for the impaired and reference watersheds. MRLC land use coverages were used to calculate the area of each land use category in impaired and reference watersheds, respectively. The breakup of the landuse in the impaired and reference watershed are given below in Tables A-2 and A-3. Note that this is a further subdivision of the landuse categories presented in the main TMDL report, where deciduous forest, evergreen forest, and mixed forest have been combined into the forest category, and where woody wetlands and emergent herbaceous wetlands have been combined into the wetlands category.

*Curve number:* This parameter determines the amount of precipitation that infiltrates into the ground or enters surface water as runoff. It is based on specified combinations of land use/cover and hydrologic soil type and is calculated directly using digital land use and soils coverages. Soils data were obtained the State Soil Geographic (STATSGO) database for the respective watersheds, as developed by the Natural Resources Conservation Services (NRCS).

*K factor:* This factor relates to inherent soil erodibility, and it affects the amount of soil erosion taking place on a given unit of land. The K factor and other Universal Soils Loss Equation (USLE) parameters were downloaded from the NRCS Natural Resources Inventory (NRI) database (1992). Average values for specific crops/land uses in each watershed county were used.

*LS factor:* This factor signifies the steepness and length of slopes in an area and directly affects the amount of soil erosion.

*C factor:* This factor is related to the amount of vegetative cover in an area. In agricultural areas, this factor is largely controlled by the crops grown and the cultivation practices used. Values range from 0 to 1.0, with larger values indicating a lower potential for erosion.

*P factor:* This factor is directly related to the conservation practices used in agricultural areas. Values range from 0 to 1.0, with larger values indicating a lower potential for erosion.

*Sediment delivery ratio:* This parameter specifies the percentage of eroded sediment delivered to surface water and is empirically based on watershed size.

*Unsaturated available water-holding capacity:* This parameter relates to the amount of water that can be stored in the soil and affects runoff and infiltration.

*Dissolved nitrogen in runoff:* This parameter varies according to land use/cover type. Reasonable values have been established in the literature. This rate, reported in milligrams per liter, can be readjusted based on local conditions such as rates of fertilizer application and farm animal populations. The default values reported in literature were used.

**Table A-2.** Landuse in the Appoquinimink River Watershed (in square miles)

| LANDUSE | Subbasin 1 | Subbasin 2 | Subbasin 3 | Subbasin 4 | Subbasin 5 | Subbasin 6 | Subbasin 7 | TOTAL |
|---|---|---|---|---|---|---|---|---|
| Open Water | 0.298 | 0.232 | 0.345 | 0.071 | 0.082 | 0.344 | 0.104 | **1.474** |
| Low Intensity | 0.064 | 0.148 | 0.000 | 0.222 | 0.291 | 0.127 | 0 | **0.852** |
| High Intensity Residential | 0.000 | 0.006 | 0.000 | 0.039 | 0.049 | 0.008 | 0 | **0.102** |
| High Intensity Commercial/ | 0.064 | 0.043 | 0.007 | 0.137 | 0.037 | 0.026 | 0.007 | **0.321** |
| Disturbed | 0.000 | 0 | 0.000 | 0.008 | 0.02 | 0.000 | 0 | **0.028** |
| Deciduous Forest | 1.237 | 0.872 | 0.11 | 0.737 | 0.496 | 1.237 | 0.216 | **4.906** |
| Evergreen Forest | 0.088 | 0.059 | 0.027 | 0.031 | 0.054 | 0.093 | 0.036 | **0.388** |
| Mixed Forest | 0.162 | 0.167 | 0.009 | 0.092 | 0.104 | 0.278 | 0.06 | **0.872** |
| Pasture/Hay | 2.093 | 0.907 | 0.298 | 1.272 | 1.454 | 1.812 | 0.574 | **8.41** |
| Row Crops | 5.261 | 2.194 | 0.417 | 3.868 | 5.100 | 4.475 | 2.216 | **23.532** |
| Other Grasses | 0.000 | 0.008 | 0.000 | 0.005 | 0 | 0 | 0 | **0.013** |
| Woody Wetlands | 0.335 | 0.047 | 0.000 | 0.143 | 0.028 | 0.129 | 0.048 | **0.729** |
| Emergent Herbaceous | 0.503 | 1.121 | 1.820 | 0.049 | 0.080 | 0.087 | 0.872 | **4.532** |
| **Total** | **10.11** | **5.80** | **3.03** | **6.68** | **7.79** | **8.62** | **4.13** | **46.16** |

**Table A-3.** Landuse in the Morgan Creek Watershed (in square miles)

| LANDUSE | Area |
|---|---|
| Open Water | 0.12 |
| Low Intensity Residential | 0.09 |
| Commercial/Industrial/Transportation | 0.04 |
| Deciduous Forest | 0.42 |
| Evergreen Forest | 0.03 |
| Mixed Forest | 0.08 |
| Pasture/Hay | 4.36 |
| Row Crops | 6.66 |
| Woody Wetlands | 0.56 |
| Emergent Herbaceous Wetlands | 0.03 |
| Total | **12.39** |

*Dissolved phosphorus in runoff:* Similar to nitrogen, the value for this parameter varies according to land use/cover type, and reasonable values have been established in the literature. This rate, reported in milligrams per liter, can be readjusted based on local conditions such as rates of fertilizer application and farm animal populations. The default values reported in literature were used.

*Nutrient concentrations in runoff over manured areas:* These concentrations are user-specified concentrations for nitrogen and phosphorus that are assumed to be representative of surface water runoff leaving areas on which manure has been applied. As with the runoff rates described above, these concentrations are based on values obtained from the literature. They also can be adjusted based on local conditions such as rates of manure application or farm animal populations. The default values reported in literature were used.

*Background nitrogen and phosphorus concentrations in soil:* Because soil erosion results in the transport of nutrient-laden sediment to nearby surface water bodies, reasonable estimates of background concentrations in soil must be provided. This information was based on literature values that were adjusted locally depending on manure loading rates and farm animal populations.

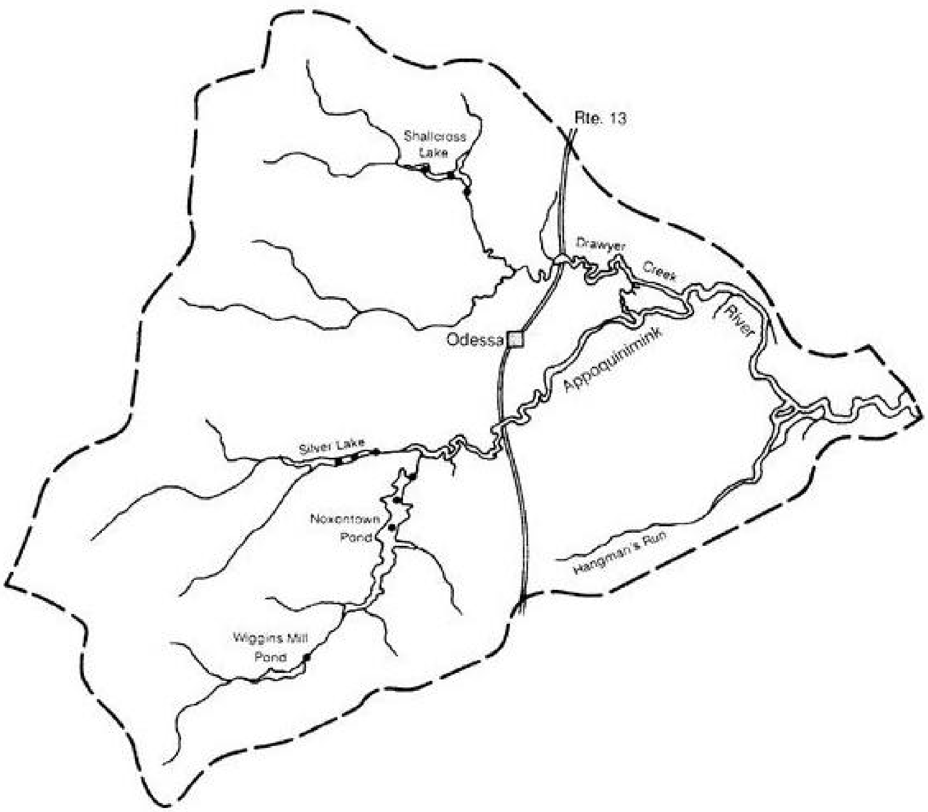
*Nutrient buildup in nonurban areas:* In GWLF, rates of buildup for both nitrogen and phosphorus have to be specified. These rates are estimated using published literature values and adjusted to local conditions.

Background nitrogen and phosphorus concentrations in groundwater: Subsurface concentrations of nutrients (primarily nitrogen and phosphorus) contribute to the nutrient loads in streams. Nutrient concentrations in groundwater were based on the results from a nationwide study of mean dissolved nutrients as measured in streamflow (as reported in Haith et al. 1992).

Other less important factors that can affect sediment and nutrient loads in a watershed also are included in the model. More detailed information about these parameters and those outlined above can be obtained from the GWLF User's Manual (Haith et al. 1992). Pages 15 through 41 of the manual provide specific details that describe equations and typical parameter values used in the model.

# Appendix B: DNREC's Technical Analysis for the Proposed Appoquinimink River TMDLs - October 2001.

# Technical Analysis for the Proposed Appoquinimink River TMDLs - October 2001





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# TABLE OF CONTENTS

# TABLE OF FIGURES

# TABLE OF TABLES

# EXECUTIVE SUMMARY

Section 303(d) of the Clean Water Act (CWA) requires States to identify and establish a priority ranking for waters in which existing pollution controls are not sufficient to attain and maintain State water quality standards, establish Total Maximum Daily Loads (TMDLs) for those waters, and periodically submit the list of impaired waters (303(d) list) and TMDLs to the United States Environmental Protection Agency (EPA).

Due to their high nutrient concentrations and/or low dissolved oxygen levels, the Delaware Department of Natural Resources and Environmental Control (DNREC) has identified and included in the States 1996, 1998, and/or proposed 2000 303(d) lists the following segments of the Appoquinimink River and its tributaries and ponds as impaired:

- Lower Appoquinimink River (DE010-001-01)
- Upper Appoquinimink River (DE010-001-02 )
- Drawyer Creek (DE010-001-03)
- Wiggins Mill Pond to confluence with Silver Lake (DE010-002-01)
- Deep Creek to confluence with Silver Lake (DE010-002-02)
- Noxontown Pond (DE010-L01)
- Silver Lake (DE010-L02)
- Shallcross Lake (DE010-L03)

A court-appointed Consent Decree (C.A> No. 960591, D. Del 1996) requires that the Appoquinimink TMDL be established by December, 2001.

The proposed Appoquinimink River TMDL is based on an assessment of the water quality condition of the Appoquinimink River and its tributaries and ponds during design conditions under various levels of point and nonpoint source loading levels. A calibrated and verified hydrodynamic water quality of the Appoquinimink River and its tributaries and ponds model was used as an assessment tool. The Appoquinimink River Model was developed using extensive hydrological and water quality data collected from 1991 through 1993 and from 1997 through 2000.

Considering the results of the assessment, DNREC has determined that in order to meet the State's water quality standards and targets, the point and nonpoint source nutrients loads (nitrogen and phosphorous) and oxygen consuming compounds (CBOD5) within the watershed should be reduced as described in Table ES-1. The proposed Appoquinimink River TMDL includes a Load Allocation (LA) for nonpoint sources and a Waste Load Allocation (WLA) for point source discharges. The margin of safety for the Appoquinimink River TMDL is considered to be implicit as the result of the consideration of conservative assumptions made during the TMDL analysis.

**Table ES-1 Proposed TMDL Loads for the Appoquinimink Watershed**

| Source | Flow (mgd) | Total N (lb/d) | Total P (lb/d) | CBOD5 (lb/d) |
|---|---|---|---|---|
| Waste Load Allocation (WLA) for Point Source: MOT | 0.5 | 10.4 | 2.1 | 34.8 |
| Load Allocation (LA) for Nonpoint Sources | - | 334.1 | 18.0 | - |
| Proposed TMDL Total Loads | - | 344.5 | 20.1 | 34.8 |

# 1. Introduction/Background

Under Section 303(d) of the Clean Water Act (CWA), States are required to identify and establish a priority ranking for waters in which existing pollution controls are not sufficient to attain and maintain State water quality standards, establish Total Maximum Daily Loads (TMDLs) for those waters, and periodically submit the list of impaired waters (303(d) list) and TMDLs to the United States Environmental Protection Agency (EPA). If a State fails to adequately meet the requirements of section 303(d), the CWA requires the EPA to establish a 303(d) list and/or determine TMDLs for that State.

In 1996, the EPA was sued under Section 303(d) of the CWA concerning the 303(d) list and TMDLs for the State of Delaware. The suit maintained that Delaware had failed to fulfill all of the requirements of Section 303(d) and the EPA had failed to assume the responsibilities not adequately preformed by the State. A settlement in the suit was reached and the Delaware Department of Natural Resources and Environmental Control (DNREC) and the EPA signed a Memorandum of Understanding (MOU) on July 25, 1997. Under the settlement, DNREC and the EPA agreed to complete TMDLs for all 1996 listed waters on a 10-year schedule.

In the Appoquinimink River watershed, a number of river segments, tributaries and ponds have been included on the State's Clean Water Action Section 303(d) List of Waters needing Total Maximum Daily Loads (Table 1-1, Figure 1-1). TMDLs need to be established for dissolved oxygen, nutrients (nitrogen and phosphorus) and bacteria concentrations.

The development of a TMDL for a particular water body typically requires the application of a receiving water model, which simulates the movement and transformation of pollutants through the water body. This can be used to predict water quality conditions under different pollutant loading scenarios to determine the loading scenario that will allow ambient conditions to meet water quality standards.

In 1998, EPA Region III, in cooperation with DNREC adopted a TMDL for the main stem of the Appoquinimink River (DE010-001-01, DE010-001-02) using a DYNHYD-WASP model. This TMDL expanded the Phase 1 TMDL developed by DNREC in 1992. The focus of the 1998 TMDL was to address water quality impairments due to low dissolved oxygen concentrations violating the daily standard of 5.5 mg/L. The TMDL called for reductions in phosphorus, carbon (carbonaceous biochemical oxygen demand [CBOD5]) and nitrogen [ammonia, and organic nitrogen] from both point and non-point sources.

TMDLs are required for the tributaries and ponds within the Appoquinimink River Watershed prior to December 2001, therefore, the 1998 DYNHYD-WASP model was expanded to include it's tributaries and ponds (DE010-001-03, DE010-002-01, DE010-002-02, DE010-L01, DE010-L02, DE010-L03). They include: Drawyer Creek, Deep Creek, Shallcross Lake, Silver Lake, Noxontown Lake and Wiggins Mill Pond (Figure 1-1). The expanded model (ARM1) will be built upon the TMDLs developed in 1998.

**Table 1-1 Appoquinimink River Watershed Segments listed on the Proposed 2000 303(d) List**

| Waterbody ID (Total Size) | Watershed Name | Segment | Description | Size Affected | Pollutant(s) and/or Stressors | Probable Sources | Year Listed | Target Date for TMDL |
|---|---|---|---|---|---|---|---|---|
| DE010-001-01 (7.1 miles) | Appoquinimink River | Lower Appoquinimink River | Saline Tidal Reach, excluding Hangman's Run | 7.1 miles | Nutrients, DO | PS, NPS | 1996 | Established 1998 (for Nutrients and DO) |
| | | | | | Bacteria, PCBs, Dioxins | NPS | 2000 | 2006 (for Bacteria) |
| | | | | | | | | 2011 (for PCBs, Dioxin) |
| DE010-001-02 (6.1 miles) | Appoquinimink River | Upper Appoquinimink River | Freshwater Tidal Reach | 6.1 miles | Nutrients, DO | PS, NPS | 1996 | Established 1998 (for Nutrients and DO) |
| | | | | | Bacteria | PS, NPS | 2000 | 2006 |
| | | | | | PCBs, Dioxins | NPS | 2000 | 2011 |
| DE010-001-03 (19.5 miles) | Appoquinimink River | Drawyer Creek | From the headwaters of Drawyer Creek to the confluence with the Appoquinimink River, including Shallcross Lake | 8.2 miles | Bacteria, Nutrients, DO | NPS | 1996 | 2001 (for Nutrients and DO) |
| | | | | | | | | 2006 (for Bacteria) |
| | | | Tributary of Drawyer Creek--from the confluence of the headwaters to the confluence with the mainstem | 2.30 miles | Biology and Habitat | NPS | 1998 | 2011 |
| | | | Western tributary of the headwaters of Drawyer Creek to its confluence | 2.20 miles | Habitat | NPS | 1998 | 2011 |
| DE010-001-03 (19.5 miles) | Appoquinimink River | Drawyer Creek | Tidal Portion | | PCB,DDT | NPS | 2000 | 2011 |
| DE010-002-01 (3.4 miles) | Appoquinimink River | Wiggins Mill Pond to confluence with Silver Lake | From the headwaters of Wiggins Mill Pond to the confluence with Noxontown Pond | 3.4 miles | Bacteria, DO | NPS | 1996 | 2001 (for DO) |
| | | | | | | | | 2006 (for Bacteria) |
| | | | | | Nutrients | NPS | 2000 | 2001 |
| | | | From the confluence of the headwaters of Wiggins Mill Pond to the confluence with Noxontown Pond | 1.62 miles | Biology | NPS | 1998 | 2011 |

| Waterbody ID (Total Size) | Watershed Name | Segment | Description | Size Affected | Pollutant(s) and/or Stressors | Probable Sources | Year Listed | Target Date for TMDL |
|---|---|---|---|---|---|---|---|---|
| DE010-002-02 (4.4 miles) | Appoquinimink River | Deep Creek to confluence with Silver Lake | From the headwaters of Deep Creek to confluence with Silver Lake, excluding Silver Lake | 2.4 miles | DO | NPS | 1996 | 2001 |
| | | | | | Bacteria, Nutrients | NPS | 2000 | 2001 (for Nutrients) |
| | | | | | | | | 2006 (for Bacteria) |
| | | | First western tributary after the headwaters of Silver Lake | 1.98 miles | Biology | NPS | 1998 | 2011 |
| | | | Deep Creek.-- from the confluence of the headwaters to Appoquinimink River | 1.84 miles | Biology | NPS | 1998 | 2011 |
| DE010-L01 (158.6 acres) | Appoquinimink River | Noxontown Pond | Pond southwest of Odessa | 158.6 acres | Bacteria, Nutrients | NPS | 1998 | 2001 (for Nutrients) |
| | | | | | | | | 2006 (for Bacteria) |
| DE010-L02 (38.7 acres) | Appoquinimink River | Silver Lake | Lake adjacent to Middletown, below Deep Creek | 38.7 acres | Bacteria, Nutrients | NPS | 1996 | 2001 (for Nutrients) |
| | | | | | | | | 2006 (for Bacteria) |
| | | | | | PCB, Dieldrin, DDT, Dioxin | NPS | 2000 | 2011 |
| DE010-L03 (43.1 acres) | Appoquinimink River | Shallcross Lake | Lake above Drawyer Creek | 43.1 acres | Bacteria, Nutrients | NPS | 1996 | 2001 (for Nutrients) |
| | | | | | | | | 2006 (for Bacteria) |

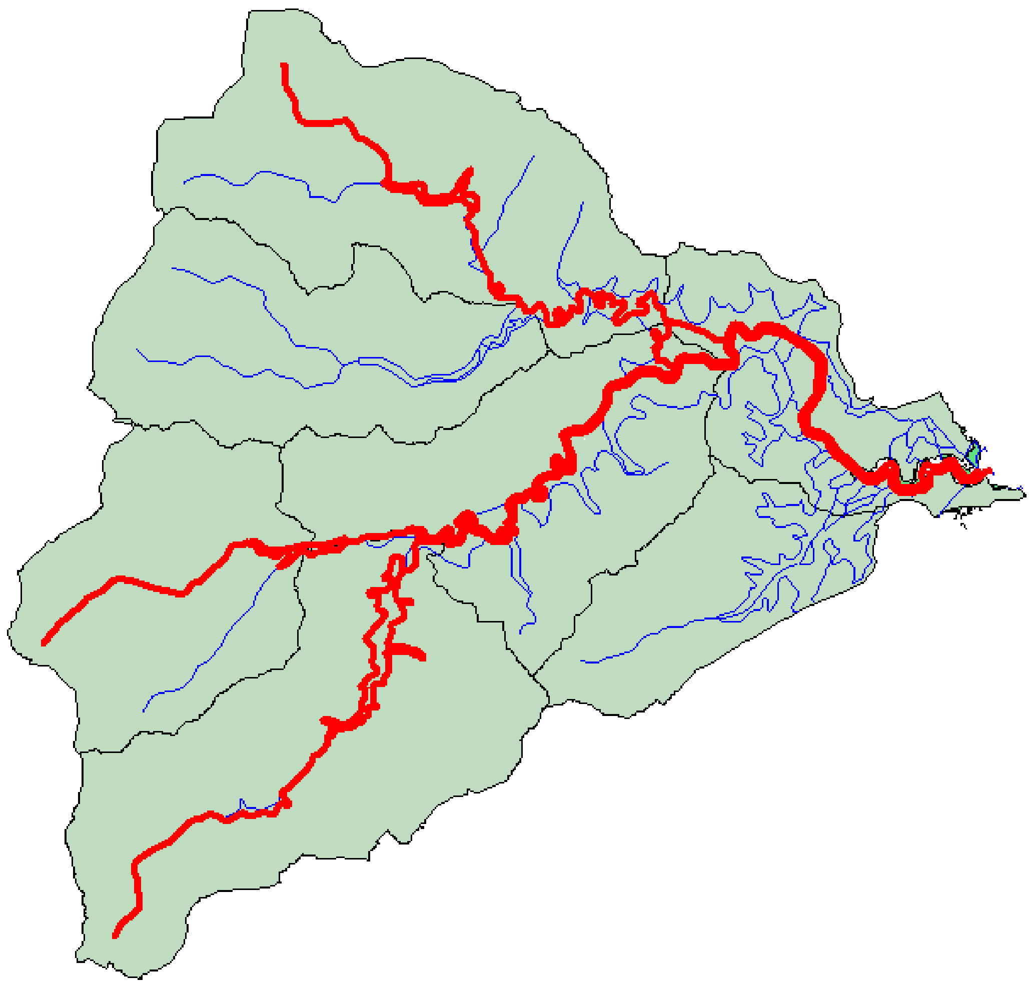

**Figure 1-1 Segments within the Appoquinimink River Watershed included in the 1998 303(d) Listing**

## 2. The Appoquinimink River Watershed

The Appoquinimink River watershed is located in the flat coastal plain of eastern Delaware (New Castle County). The watershed is approximately 47 square miles and can be described as primarily agricultural with three residential/urban centers: Middletown, Odessa and Townsend. The land is generally characterized as flat to gently sloping, which is typical of the coastal plain.

The Appoquinimink River system consists of three main branches. Moving south to north, it includes: the Appoquinimink River (Wiggins Mill Pond and Noxontown Lake); Deep Creek (Silver Lake); and Drawyer Creek (Shallcross Lake). The ponds and lakes included in the Appoquinimink River Watershed are typically shallow, man-made ponds maintained by dams.

The system is tidal up to the outlet dams of Noxontown Lake on the Appoquinimink River main stem, Silver Lake on Deep Creek, and the Drawyer Creek's confluence with the Appoquinimink River. The salinity from Delaware Bay typically extends past the Drawyer Creek - Appoquinimink confluence at river kilometer (Rkm) 8.5. The only point source within the system is the Middletown-Odessa-Townsend wastewater treatment plant (MOT WWTP) located at Rkm 10 which primarily uses spray irrigation to dispose of its effluent but may occasionally discharge into the surface waters of the Appoquinimink River.

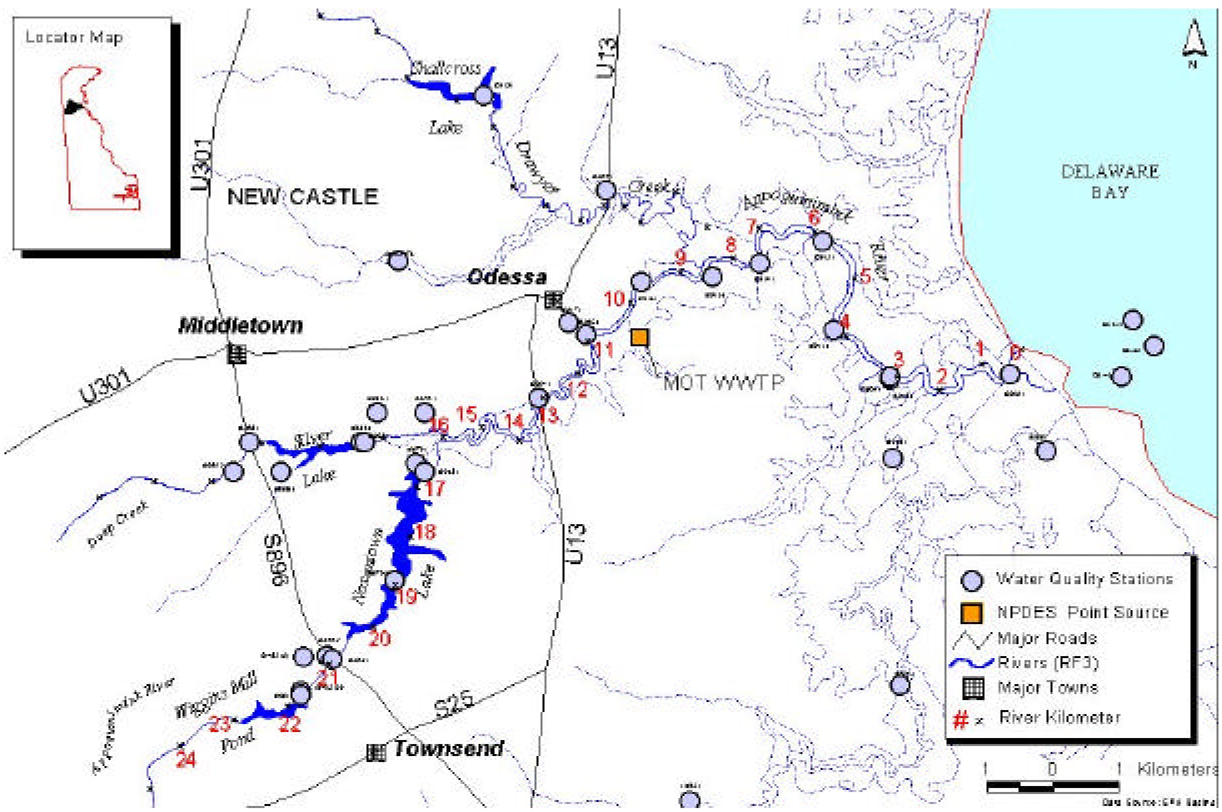


**Figure 2-1 Study Area**

## 2.1. Designated Uses

Section 10 of the State of Delaware Surface Water Quality Standards, as amended August 11, 1999, specifies the following designated uses for the waters of the Appoquinimink River watershed:

1. Primary Contact Recreation
2. Secondary Contact Recreation
3. Fish, Aquatic Life, and Wildlife
4. Industrial Water Supply
5. Agricultural Water Supply (freshwater segments)

## 2.2. Applicable Water Quality Standards

The following sections of the State of Delaware Surface Water Quality Standards, as amended August 11, 1999, provide specific narrative and/or numeric criteria concerning the waters of the Appoquinimink River Watershed:

1. Section 3: General guidelines regarding Department's Antidegradation policies
2. Section 7: Specific narrative and numeric criteria for controlling nutrient overenrichment in waters of the State
3. Section 9: Specific narrative and numeric criteria for toxic substances
4. Section 11: General water criteria for surface waters of the State

According to Section 11 and 7 of the Standards, the following water quality criteria are applicable to fresh and/or marine waters of the Appoquinimink River:

A. Disolved Oxygen (DO)

   a. 5.5 mg/L daily average (from June through September) for fresh waters. Fresh waters are defined as those having a salinity of less than 5 parts per thousand

   b. 5.0 mg/L daily average (from June through September) for marine waters. Marine waters are defined as those having a salinity of equal to or greater than 5 parts per thousand.

   c. 4.0 mg/L minimum at any time of both fresh and marine waters.

Based on the salinity data (Figure 2-2), all portions of the Appoquinimink River and it's tributaries are considered to be fresh water because the minimum salinity levels are less than 5 ppt.

B. Enteroccus Bacteria

   a. For fresh waters, the geometric average of representative samples should not exceed 100 colonies/100 mL.

C. Nutrients

a. Section 7 of the Standards uses a narrative statement for controlling nutrient overenrichment of the State's surface waters. It states; "*Nutrient overenrichment is recognized as a significant problem in some surface waters of the State. It shall be the policy of this Department to minimize nutrient input to surface waters from point sources and human induced nonpoint sources. Thy types of, and need for, nutrient controls shall be established on a site-specific basis. For lakes and ponds, controls shall be designed to eliminate overenrichment.*"

In the absence of numeric nutrient criteria, DNREC has decided upon threshold levels of 3.0 mg/L for total nitrogen and 0.1 mg/L for total phosphorous in determining whether a stream should be included on the State's list of impaired waters (303(d) lists). These threshold levels are generally accepted by the scientific community to be an indication of overenriched waters.

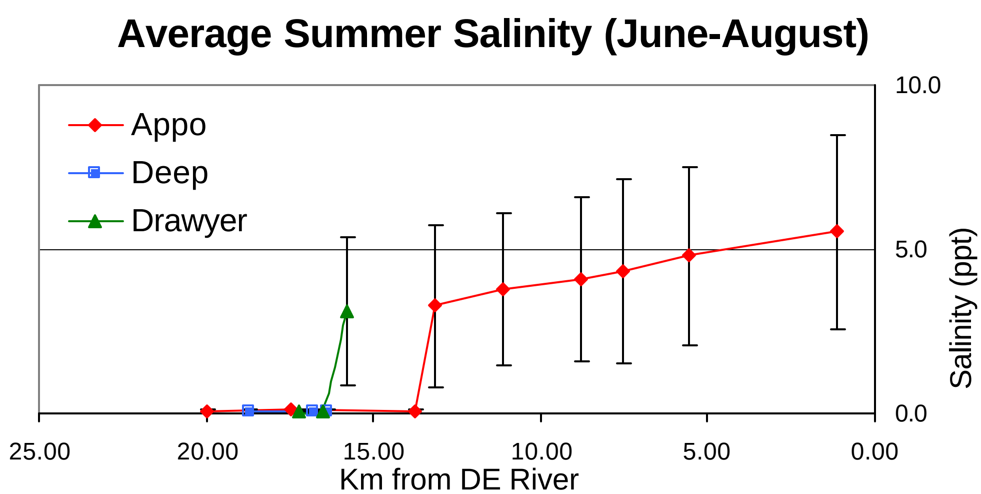


**Figure 2-2 Summer Salinity within the Appoquinimink River Watershed ('97-'00 data)**

# 3. Development of the Appoquinimink River WASP5 Model

HydroQual Inc. was contracted by the Delaware DNREC to expand, calibrate, and validate the ARM0 model to include the additional sections within the watershed listed on the 303(d) list (Section 1). The following sections are excerpts from their report, "The Appoquinimink River Watershed TMDL Model", delivered in June, 2001.

## 3.1. Previous modeling Study

The "TMDL Model Study for the Appoquinimink River, Delaware" was issued in May 1993 and included tidal hydrodynamics using DYNHYD5 (hydrodynamic submodel included in WASP5). The DYNHYD5 model of the Appoquinimink River was an advance over the earlier modeling study (Phase I TMDL, DNREC 1992), which simulated the movement of water in the estuary as steady state and tidally averaged conditions.

The Appoquinimink River was segmented into 27 nodes or junctions and 26 connecting channels. Figure 3-1 shows the WASP segmentation of the previous modeling study (ARM0). For each segment the surface area and average depth at (mean sea level) were determined for input to the DYNHYD5 hydrodynamic sub model. For each channel, the depth, length, cross-sectional area, downstream (positive flow) direction, and Manning's 'n' roughness coefficient were estimated. The channel geometries (depth and width) were estimated from data measured by the USGS at ten stations along the Appoquinimink River. The geometries for segments between the measured cross-sections were estimated by interpolation.

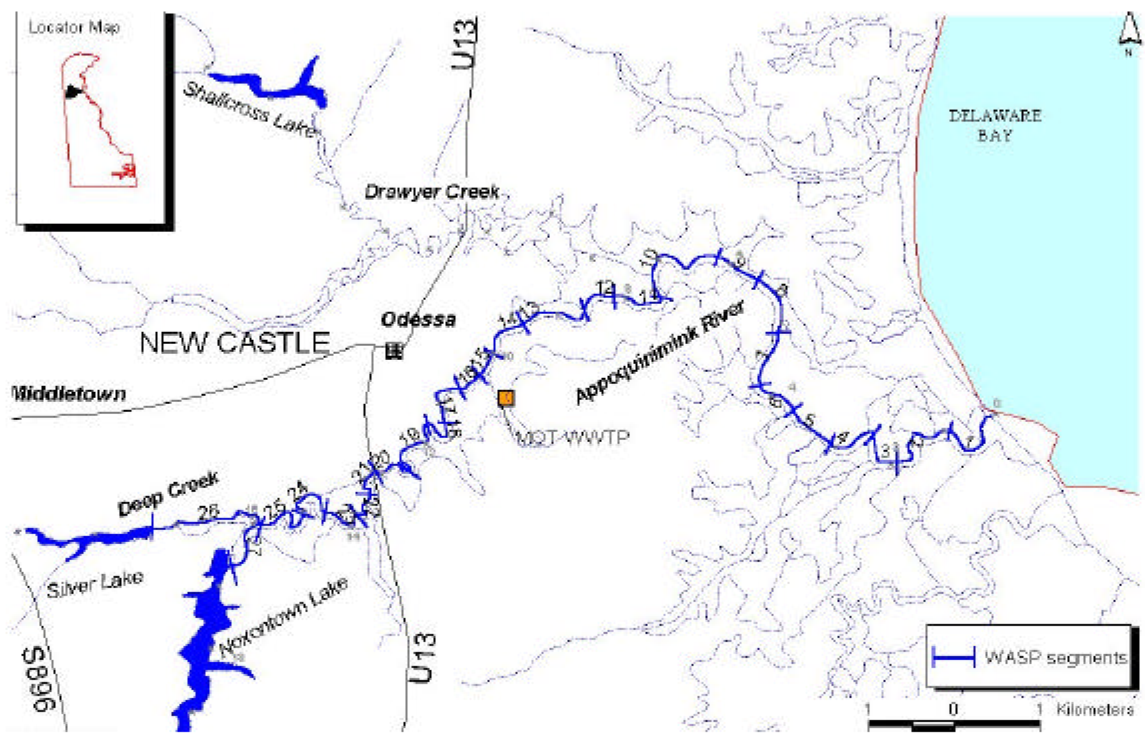


**Figure 3-1 ARM0 WASP Segmentation**

Boundary tides at the mouth of the Appoquinimink River were estimated from National Oceanic and Atmospheric Administration (NOAA) tide predictions using Reedy Point as the reference station. The times and heights of the high and low tides were then corrected to Liston Point which is about 3 miles south of the mouth of Appoquinimink River. The high and low tides over the period August 11 to October 19, 1991, were used as the boundary forcing condition in the model. Tributary flows in the model were set to constant values for the following locations for the August-October period.

| | | |
|---|---|---|
| Noxontown Pond | 4.0 cfs | Model Junction 26 |
| Silver Lake | 4.0 cfs | Model Junction 27 |
| Drawyer Creek | 13.5 cfs | Model Junction 11 |

These flows were estimated based on the drainage area of each sub watershed and flows measured by a nearby USGS gage on Morgan Creek near Kennedyville, Maryland.

## 3.2. River Geometry

### 3.2.1 Hydrodynamic Data

#### 3.2.1.1. Geometry

Expanding the existing Appoquinimink River Model (ARM0) to include upstream river reaches and lakes required additional data collection. Combined with the existing bathymetry and geometry data, the new data provided the basis for the expanded model grid. The river geometry data used to set up the new model framework came from four primary sources:

1) 1993 DYNHYD5 Model: Hydrodynamic model setup which included river geometry for the Appoquinimink River. The 1993 river geometry data was used as the basis for extending the existing hydrodynamic data. Depths, widths, flows and roughness coefficients values for the ARM0 were used to assign the values to the new tributaries.

2) RF3 files: United States Environmental Protection Agency (USEPA) - Reach File, Version 3 (RF3) data for rivers. RF3 data for rivers was used for the model segmentation. This data also provided the location and lengths of Drawyer Creek and Deep Creek.

3) USGS Topographic Maps: United States Geological Survey (USGS) 7.5 minute topographic map for elevation data and river length. The USGS topographic map of the area was used to estimate widths of Drawyer and Deep Creeks as well as the reaches of the Appoquinimink River upstream of the Noxontown Pond.

4) DNREC Survey - May 2000: DNREC collected geometry data during the Acoustic Doppler Current Profiler (ADCP) survey conducted at several sites along the Appoquinimink River on May 9, 2000. The lengths and widths collected during the ADCP survey were used in the hydrodynamic model setup (Table 3-1 , Table 3-2, Figure 3-2, Figure 3-3, Figure 3-4).

**Table 3-1 Cross Sectional Data (5/9/2000)**

| Station | Width (m) | Depth (m) | DYNHYD Segment Number |
|---|---|---|---|
| 1 | 94.35 | 4.6 | 2 |
| 2 | 74.78 | 4.1 | 6 |
| 3 | 97.32 | 2.72 | 8, 9 |
| 4 | 64.9 | 4.8 | 11 |
| 5 | 62.6 | 2.11 | 48 |
| 6 | 47.1 | 3.37 | 14 |
| 7 | 51.1 | 3.0 | 17 |

DNREC also provided geometry data for the 4 ponds/lakes located in the Appoquinimink River Watershed. These data are presented in Table 3-2 and were also used in the model segmentation setup.

**Table 3-2 Physical Characteristics of the Ponds**

| Pond | Surface Area (acres) | Dam Height (ft) |
|---|---|---|
| Noxontown Pond | 158.6 | 6 |
| Shallcross Lake | 43.3 | 8 |
| Wiggins Mill Pond | 21.2 | 15 |
| Silver Lake | 38.2 | 10 |

3.2.1.2. Flow Data

The 1993 DYNHYD5 model (ARM0) provided the flow data in the segments of the Appoquinimink River main stem. This flow output data was used to calibrate the expanded DYNHYD5 model (ARM1). The freshwater inflows, roughness coefficients and river geometry were adjusted to fit the 1993 flow data.

3.2.1.3. Tide Data

Tidal elevation data at the boundary was obtained from the 1993 DYNHYD5 model. Two periods of continuous data were available for the boundary:

1) August through October 1991 (~ 2 months)
2) May through July 1991 (~ 3 months)

The tidal elevation data at the Delaware River boundary is presented in Figure 3-5. During these two periods the tidal elevations, ranged from approximately -1 to 1 meter with a maximum tidal range of approximately 2 meters.

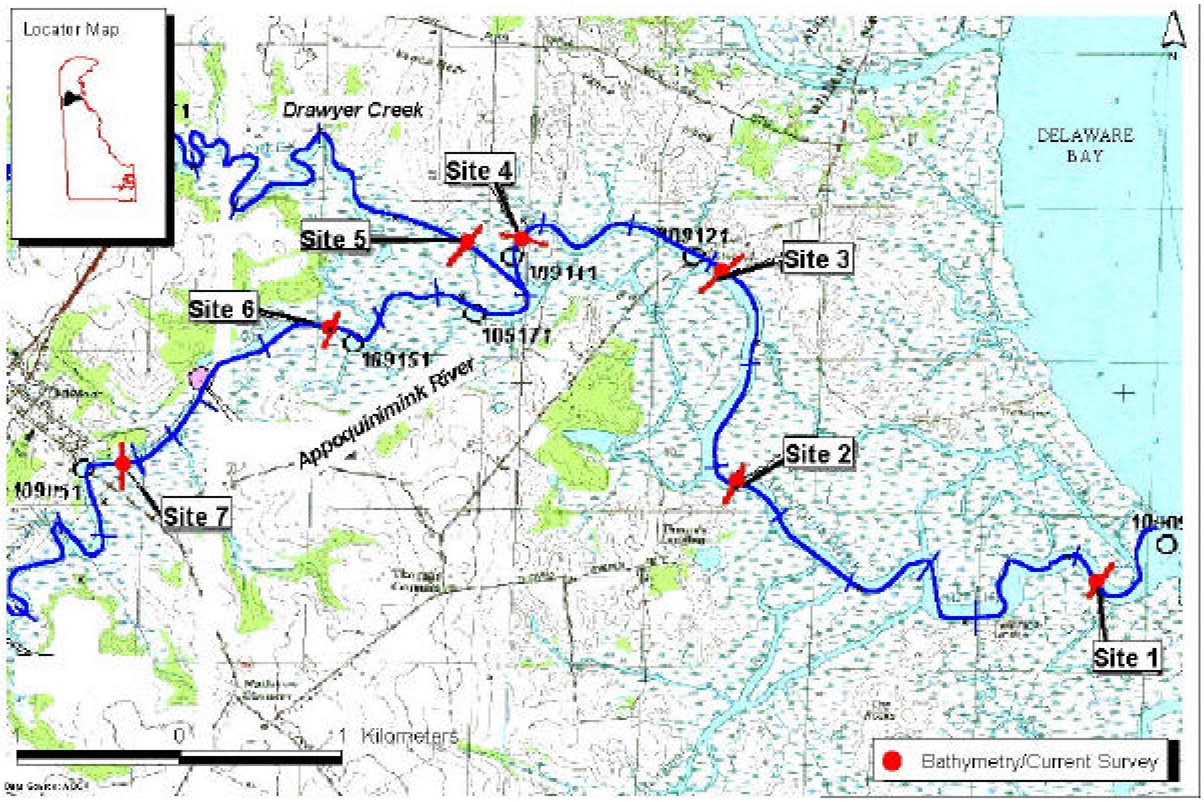


**Figure 3-2 Bathymetry Survey (5/9/2000)**

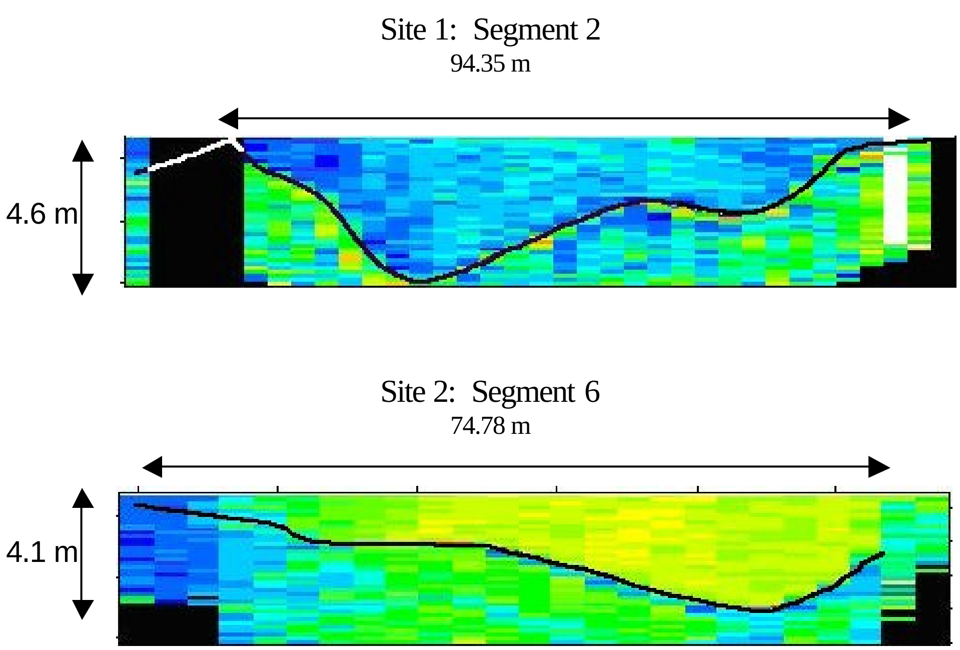


**Figure 3-3 Cross Sectional Data –Sites 1 & 2 (ADCP Survey)**

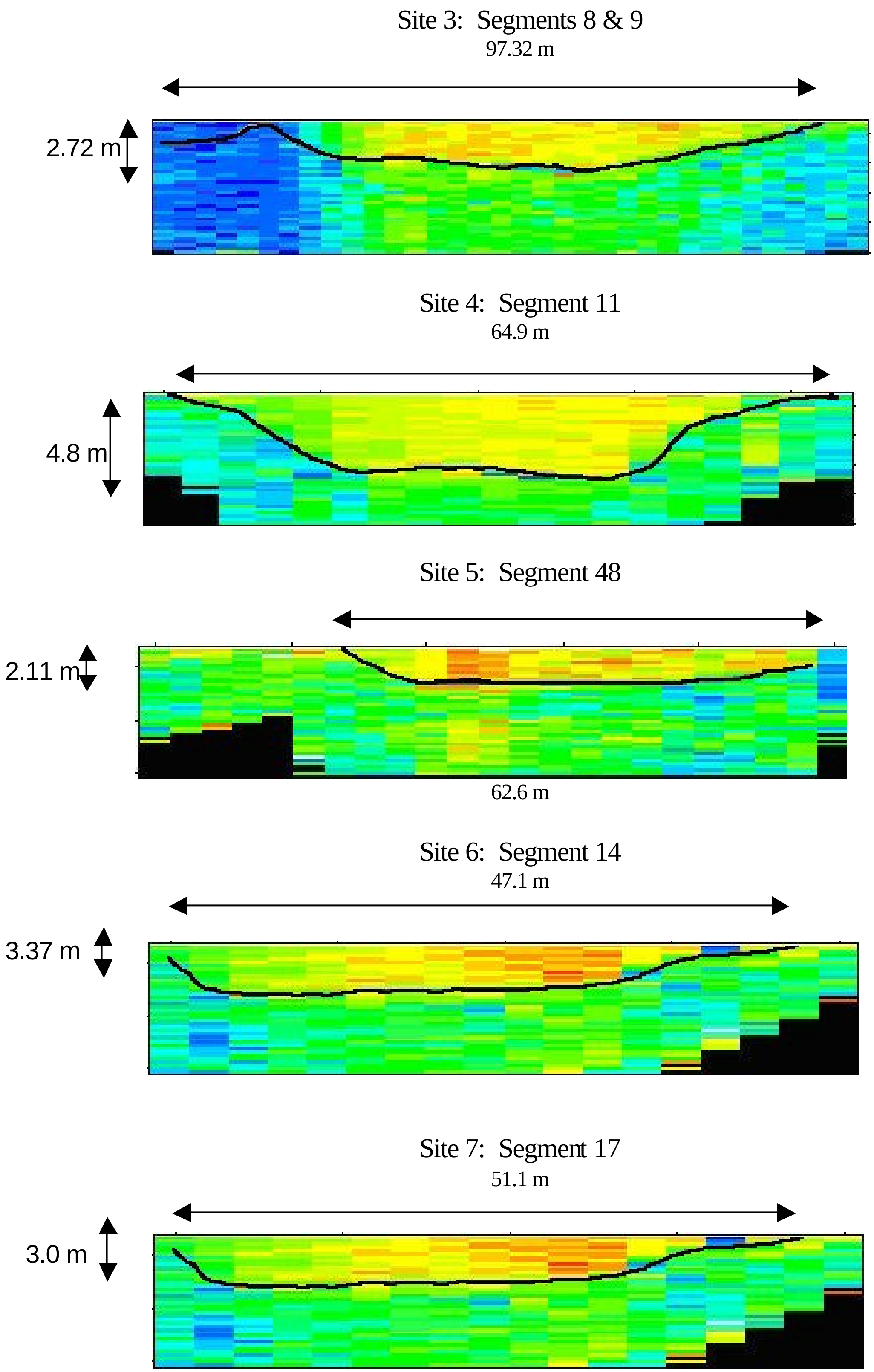


**Figure 3-4 Cross Sectional Data – Sites 3-7 (ADCP Survey)**

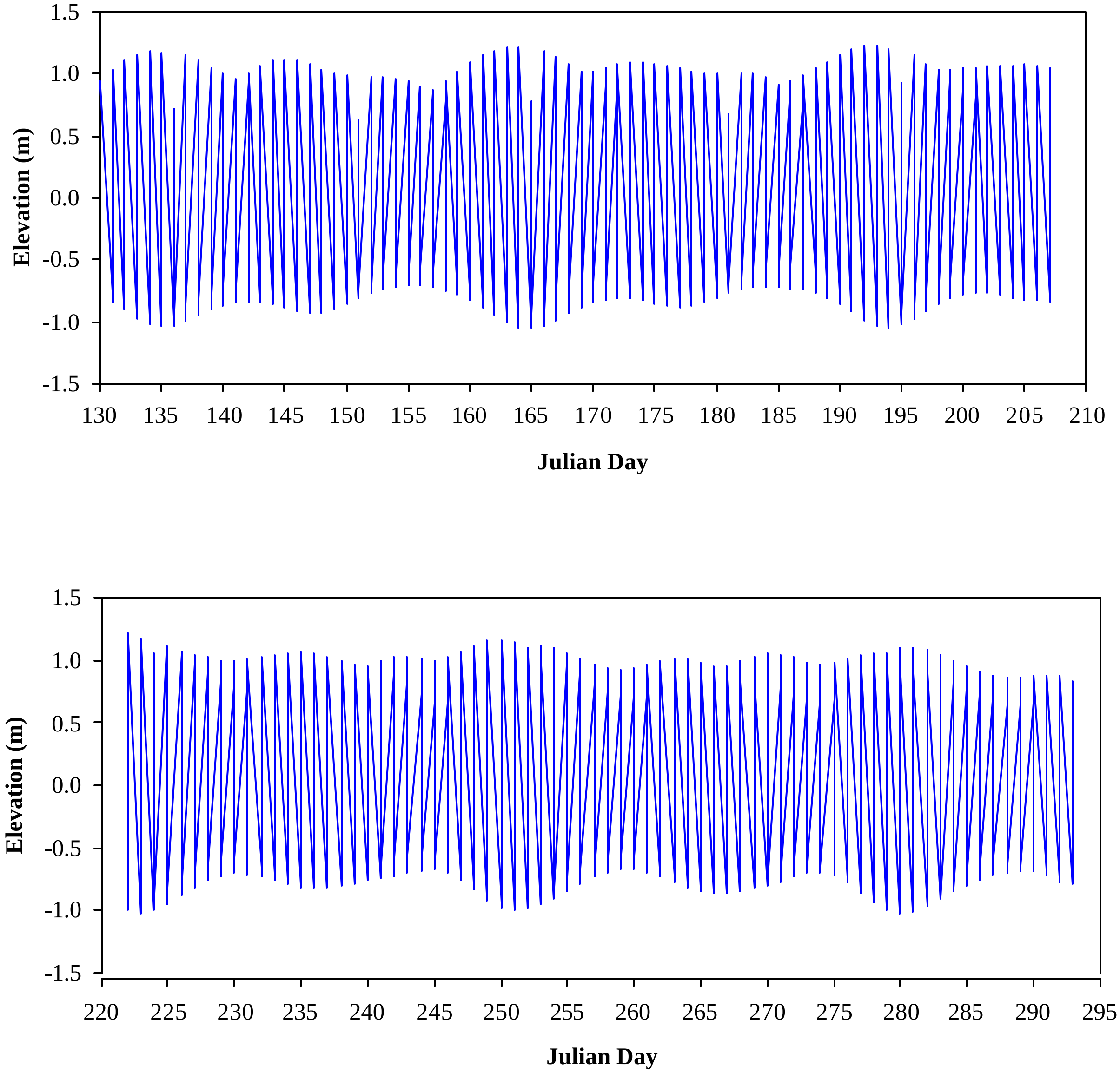


**Figure 3-5 Tidal Elevation Data at the DE River Boundary (1991)**

## 3.3. DYNHYD5 Model Framework

### 3.3.1 Theory

#### 3.3.1.1. Modeling Program

The USEPA's DYNHYD5 hydrodynamic model was used to calculate water transport within the Appoquinimink River Watershed. DYNHYD5 is part of the WASP5 water quality-modeling program and solves the one-dimensional equations of continuity and momentum for a branching channel junction (link node) computational network.

The hydrodynamic model solves equations describing the propagation of a long wave through a shallow water system while conserving both momentum (energy) and volume (mass). The equation of motion, based on the conservation of momentum, predicts water velocities and flows. The equation of continuity, based on the conservation of volume, predicts water heights (heads) and volumes. This approach assumes that:

- Flow is predominantly one-dimensional,
- Coriolis and other accelerations normal to the direction of flow are negligible,
- Channels can be adequately represented by a constant top width with a variable hydraulic depth (i.e., "rectangular"),
- The wave length is significantly greater than the depth, and
- Bottom slopes are moderate.

Although no strict criteria are available for the latter two assumptions, most natural flow conditions in large rivers and estuaries would be acceptable. Dam break situations could not be simulated with DYNHYD5, nor could small mountain streams with steep slopes.

The DYNHYD model simulates the circulation patterns of water by solving two equations:

*1) The equation of motion:*

$$\frac{\partial U}{\partial t} = -U\frac{\partial U}{\partial x} + a_{g,l} + a_f + a_{w,l}$$

where:

$\frac{\partial U}{\partial t}$ = the local inertia term, or the velocity rate of change with respect to time, [m/sec$^2$]

$U\frac{\partial U}{\partial x}$ = the Bernoulli acceleration, or the rate of momentum change by mass transfer; also defined as the convective inertial term from Newton's second law, [m/sec$^2$]

$a_{g,\lambda}$ = gravitational acceleration along with the $\lambda$ axis of the channel, [m/sec$^2$]

$a_f$ = frictional acceleration, [m/sec$^2$]

$a_{w,\lambda}$ = wind stress acceleration along axis of channel, [m/sec$^2$]

x = distance along axis of channel, [m]

t = time, [sec]

U = velocity along the axis of channel, [m/sec$^2$]

$\lambda$ = longitudinal axis

*2) The equation of continuity:*

$$\frac{\partial A}{\partial t} = -\frac{\partial Q}{\partial x}$$

where:

A = cross sectional area, [m$^2$]
Q = flow, [m$^3$/sec]

For rectangular channels of constant width (B):

$$\frac{\partial H}{\partial t} = -\frac{1}{B}\frac{\partial Q}{\partial x}$$

where:

B = width, [m]

H = water surface elavation, [m]

$\frac{\partial H}{\partial t}$ = rate of water surface elevation change with respect to time, [m/sec]

$\frac{1}{B}\frac{\partial Q}{\partial x}$ = rate of water volume change with respect to distance per unit width, [m/sec]

The equations of motion and continuity form the basis of the hydrodynamic model DYNHYD5. Their solution gives velocities (U) and heads (H) throughout the water body for the duration of the simulation. Because closed-form analytical solutions are unavailable, the solution of equations requires numerical integration on a computational network, where values of U and H are calculated at discrete points in space and time. The "link-node" network solves the equations of motion and continuity at alternating grid points. At each time step, the equation of motion is solved at the links while the equation of continuity is solved at the nodes, giving velocities for mass transport calculations and heads for pollutant concentration calculations respectively.

Picturing the links as channels conveying water and the nodes as junctions storing water allows a physical interpretation of this computational network to be envisioned. Each junction is a volumetric unit that acts as a receptacle for the water transported through its connecting channels. Taken together, the junctions account for all the water volume in the river or estuary. Parameters influencing the storage of water are defined within this junction network. Each channel is an idealized rectangular conveyor that transports water between two junctions, whose midpoints are at each end. Taken together, the channels account for all the water movement in the river or estuary. Parameters influencing the motion of water are defined within the channel network. The link-node computational network, then, can be viewed as the overlapping of two closely related physical networks of channels and junctions.

3.3.2 Model Geometry and Bathymetry

The segmentation for the expanded Appoquinimink River Watershed model (ARM1) is presented in Figure 3-6. The model is one-dimensional and consists of 51 junctions and 47 channels that average approximately one half mile in length.

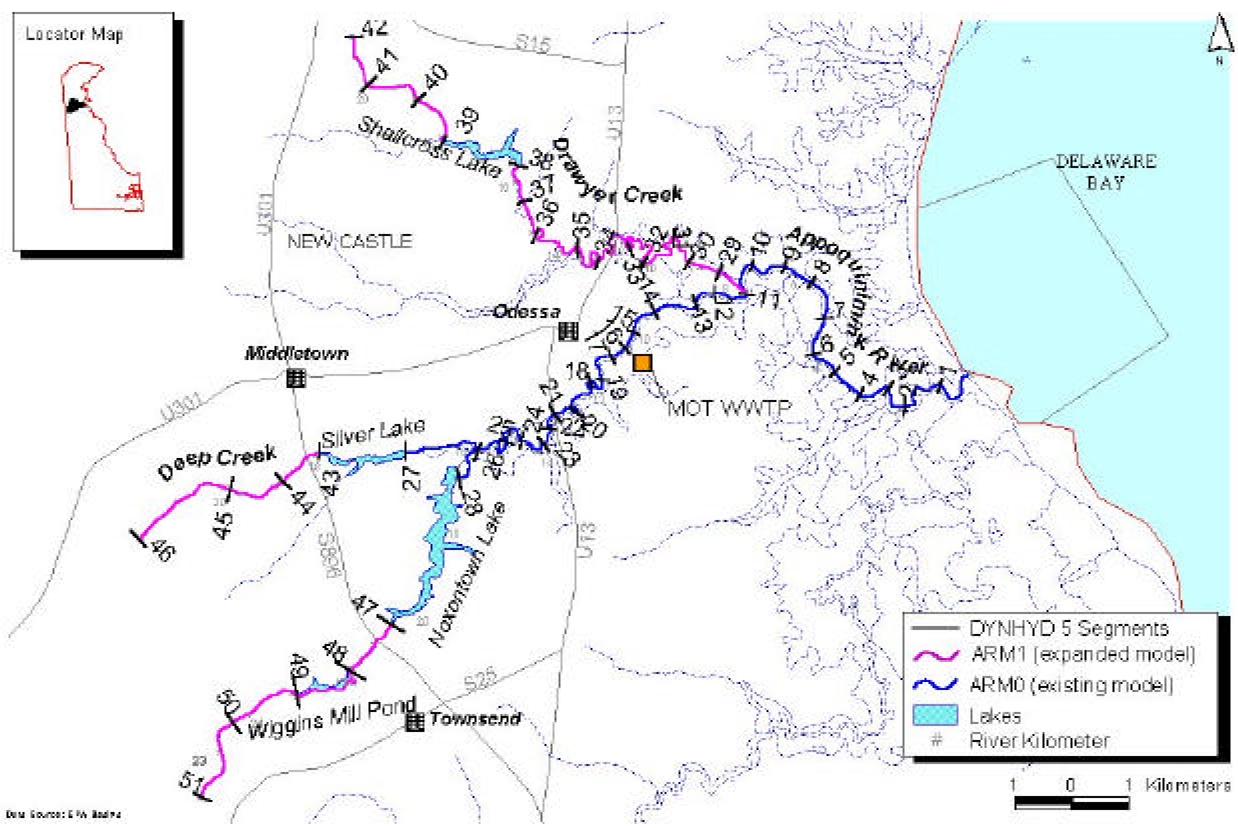


**Figure 3-6 DYNHYD5 ARM1 Junctions**

Four ponds were included in the expanded model grid: Noxontown Lake, Wiggins Mill Pond, Silver Lake and Shallcross Lake. Flow out of the ponds results from water flowing over the tops of the dams. With a dam forming a physical boundary to the free flow of water through the system, channel velocities are not propagated downstream of the ponds in the model framework. Only flows entering the pond are passed to the downstream model junction.

As previously mentioned, the data used to extend the hydrodynamic model of the Appoquinimink River was obtained from four data sources (1993 DYNHYD5 model, DNREC geometry, RF3 data and USGS topographic maps) and used in setting up the geometry (width, initial depth and elevation) for the DYNHYD5 model. None of the data sources alone provided the complete data set needed for the model grid. Therefore, best professional judgment was used to integrate the data sources into one picture of the river to resolve discrepancies and inconsistencies between and within the data sources, and to make estimates where data gaps existed.

Using the data as a guide, widths and depths were assigned for each model junction. Manning's 'n' which describes the bottom roughness, varied between 0.035 and 0.065. Increased roughness coefficients of 0.10 were used for three channels at the confluence of Drawyer Creek and the Appoquinimink River to improve the DYNHYD5 comparisons to the ARM0 model output. The roughness coefficients were adjusted based on the values of the coefficients of the previous modeling study (ARM0) geometry .

#### 3.3.2.1. Model Forcing Data

Freshwater flows at the upstream boundaries and tide data at the downstream boundary were the primary forcing functions in the model. The water loss due to evaporation from the water surface and the addition of water due to precipitation falling directly on the water surface were assumed to be of second-order importance and not included in the model framework. The direct effect of wind on the water surface was also assumed to be of second-order importance. The river channel is relatively narrow and would, therefore, not be strongly impacted by winds. The effect of wind on Delaware Bay is reflected in the tidal data and, therefore, is included in the model indirectly through the tidal data used to drive the downstream boundary. A total of four boundary conditions are included in the model; the open tidal boundary at Delaware Bay and three upstream freshwater inputs (Drawyer Creek, Deep Creek and the Appoquinimink River).

#### 3.3.2.2. Tidal Boundary

An open water boundary was located at the mouth of the river to Delaware Bay (junction 1), which is driven by the tidal conditions in the Delaware Bay.

Tidal information used in the ARM0 (1991 model setup) was used to drive the downstream model boundary. This data has been described in Section 3.2.1.3 and presented in Figure 3-5.

#### 3.3.2.3. Fresh Water Flows

Flow enters the model through one of three possible mechanisms: upstream boundaries (Drawyer Creek, Deep Creek and upstream Appoquinimink River), tributaries, or direct runoff into a model junction. Three freshwater inputs were assigned at upstream boundary for Drawyer

Creek, Deep Creek and the Appoquinimink River (Table 3-3). These freshwater inputs are constant flows and are not affected by tidal conditions in the lower Appoquinimink River. The flows for the upstream boundaries were determined based on the ratio of the drainage area of each sub basin to the drainage area of the gagged sub basin. At each of the three upstream boundary locations, the following constant flows were assigned.

**Table 3-3 Freshwater Inflows**

| Location | Junction | Inflows (cfs) |
|---|---|---|
| Drawyer Creek | 42 | 13.5 |
| Deep Creek | 46 | 4.0 |
| Appoquinimink River | 51 | 4.0 |

3.3.2.4. Initial Conditions

Initial conditions were assigned to each model segment for each system being modeled based on the ARM0 initial conditions, these conditions included the initial mean velocities (m/s). An average initial velocity of 0.001 m/s was specified for all the channels.

## 3.4. DYNHYD5 Calibration/Validation

HydroQual was contracted to expand the existing TMDL model of the Appoquinimink River (ARM0) to upstream areas not included in the original model study area. These expanded areas include Drawyer Creek and Shallcross Lake, Deep Creek and Silver Lake, and the upstream Appoquinimink River including Wiggins Mill Pond and Noxontown Lake. This new expanded model is referred to as ARM1. Since new data was not available for this phase of the model expansion, additional calibration analyses could not be completed. In addition, since the existing TMDL for the main stem of the Appoquinimink River is based on the 1993 TetraTech model (ARM0), the expanded model (ARM1) primarily used the same base-line conditions, assumptions, and parameters to avoid any inconsistencies. Therefore, the expanded hydrodynamic model (ARM1) was calibrated to match the results of the 1993 adjusted model (ARM0). The same periods used to calibrate and validate the ARM0 model (calibration: August 10, 1991 to October 14, 1991 and validation: May 10, 1991 through July 25, 1991) were also used to calibrate and validate the ARM1 model. With additional upstream segments and new geometry data, the ARM1 model was calibrated primarily by performing adjustments to Manning's 'n' and refinements to the model geometry. This is the same approach used in the 1993 calibration efforts and included adjusting parameters to conform within the ranges used in the earlier modeling work (ARM0). Inconsistencies between the ARM0 model input channel lengths and widths, and junction surface areas were corrected in the ARM1 model with the channel lengths and widths used to calculate the new surface areas. In addition, the large boundary junction required in the original ARM0 model was not required in the ARM1 model and the correct surface area was used.

3.4.1 Calibration

The model was calibrated to the period from August 10 to October 14, 1991 with results presented for 6 segments (Figure 3-7). Roughness coefficients and river geometry were adjusted to match the 1993 modeling results.

The model output in segments 1, 5, 10, 15, 20, and 25 for the calibration period generated with the new expanded model (ARM1) show agreement with the model output previously generated with the 1993 model (ARM0). Cross-plots of ARM0 and ARM1 DYNHYD5 model output is presented in Figure 3-8 through Figure 3-10 for velocity, flow and depth at junctions 1, 5, 10, 15, 20 and 25 along with a line of perfect agreement (slope = 1). The new ARM1 DYNHYD5 model generally reproduces the ARM0 model output with slightly greater flood and ebb tide velocities and flows calculated with the ARM1 model at junctions 1, 5, 10, and 25. The ARM1/ARM0 agreement at junctions 15 and 20 for velocity and flow is very good. Calculated water depths from the ARM1 model also agree very well with the ARM0 results.

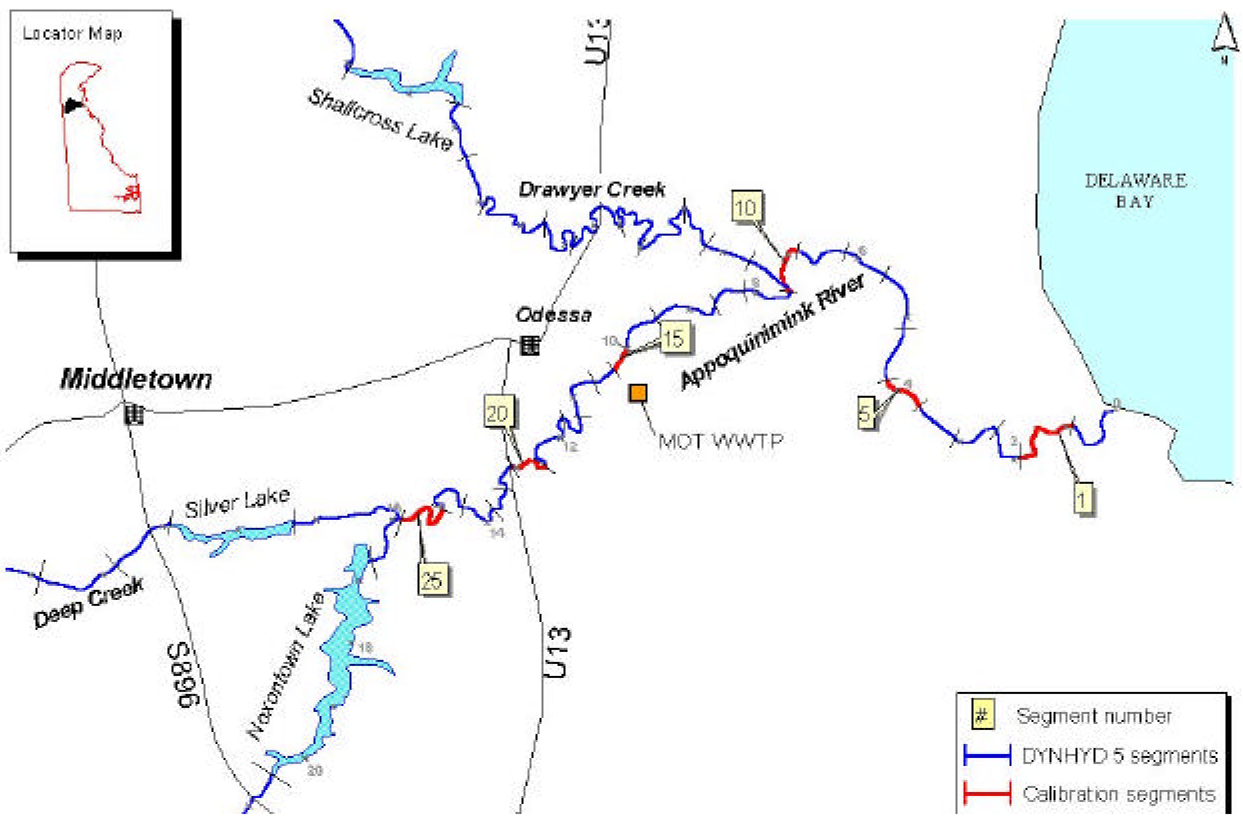


**Figure 3-7 Appoquinimink River Watershed DYNHYD5 Calibration Segments**

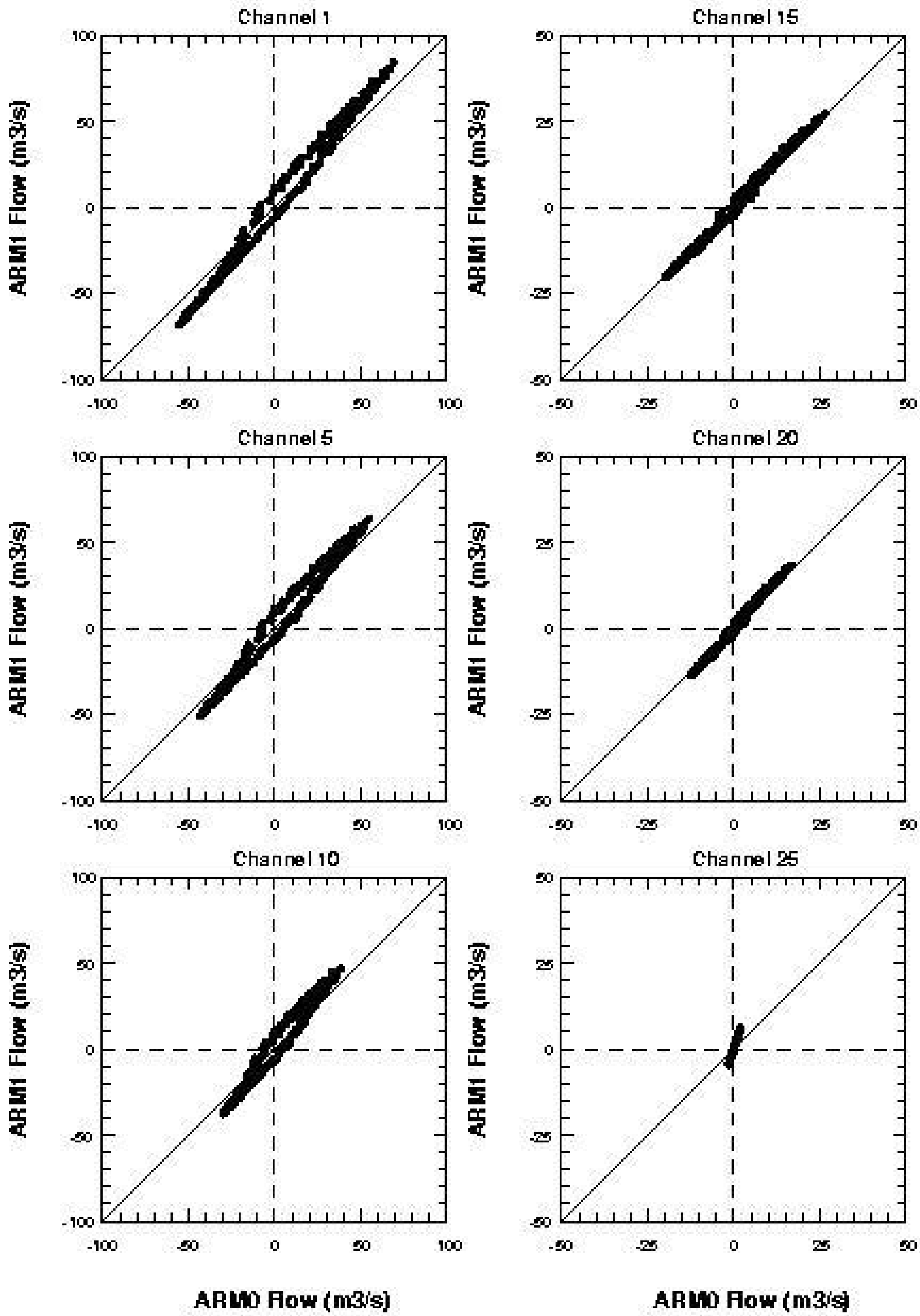


**Figure 3-8 Appoquinimink River Model DYNHYD5 Calibration Flow Comparisons**

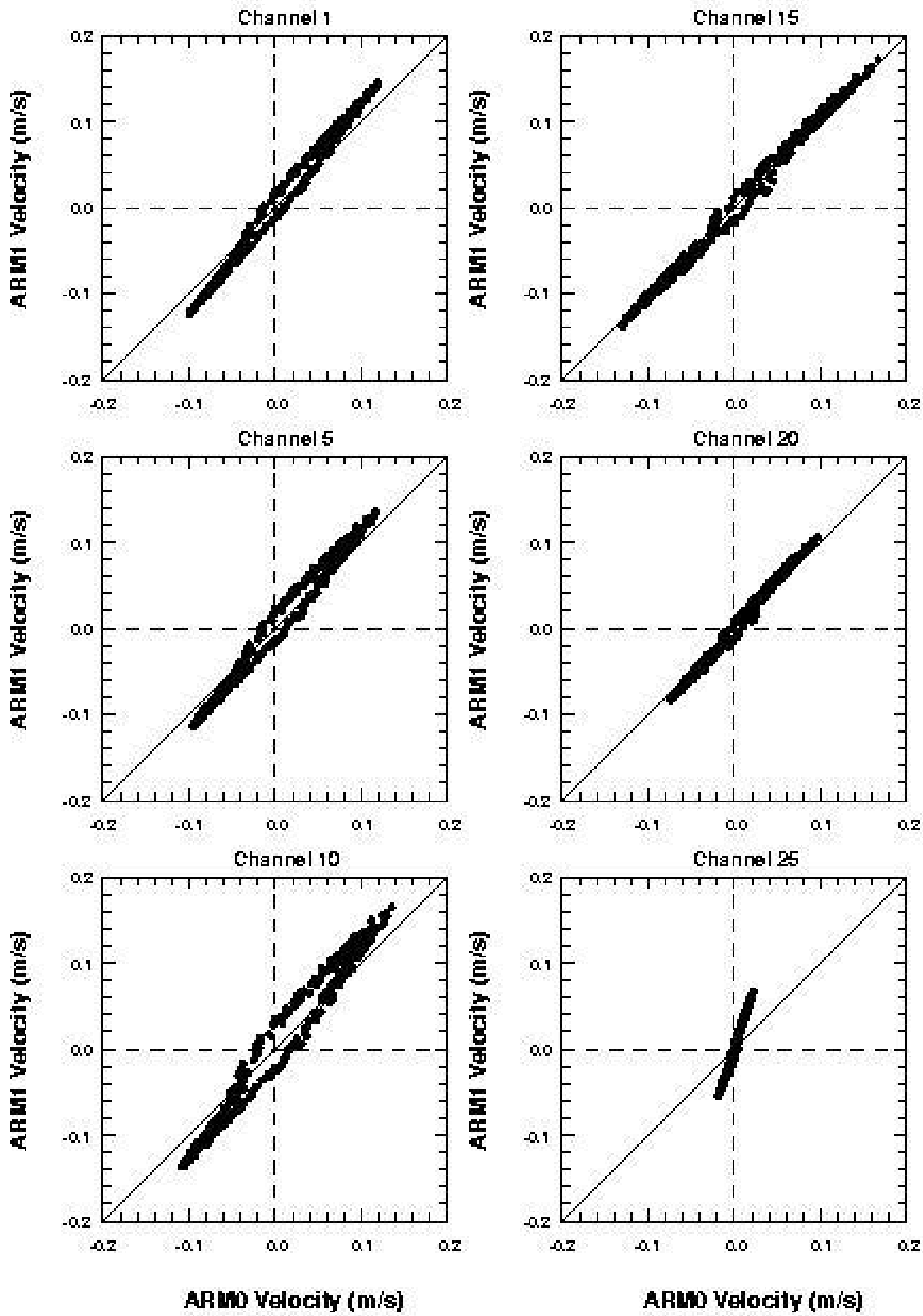


**Figure 3-9 Appoquinimink River Model DYNHYD5 Calibration Velocity Comparisons**

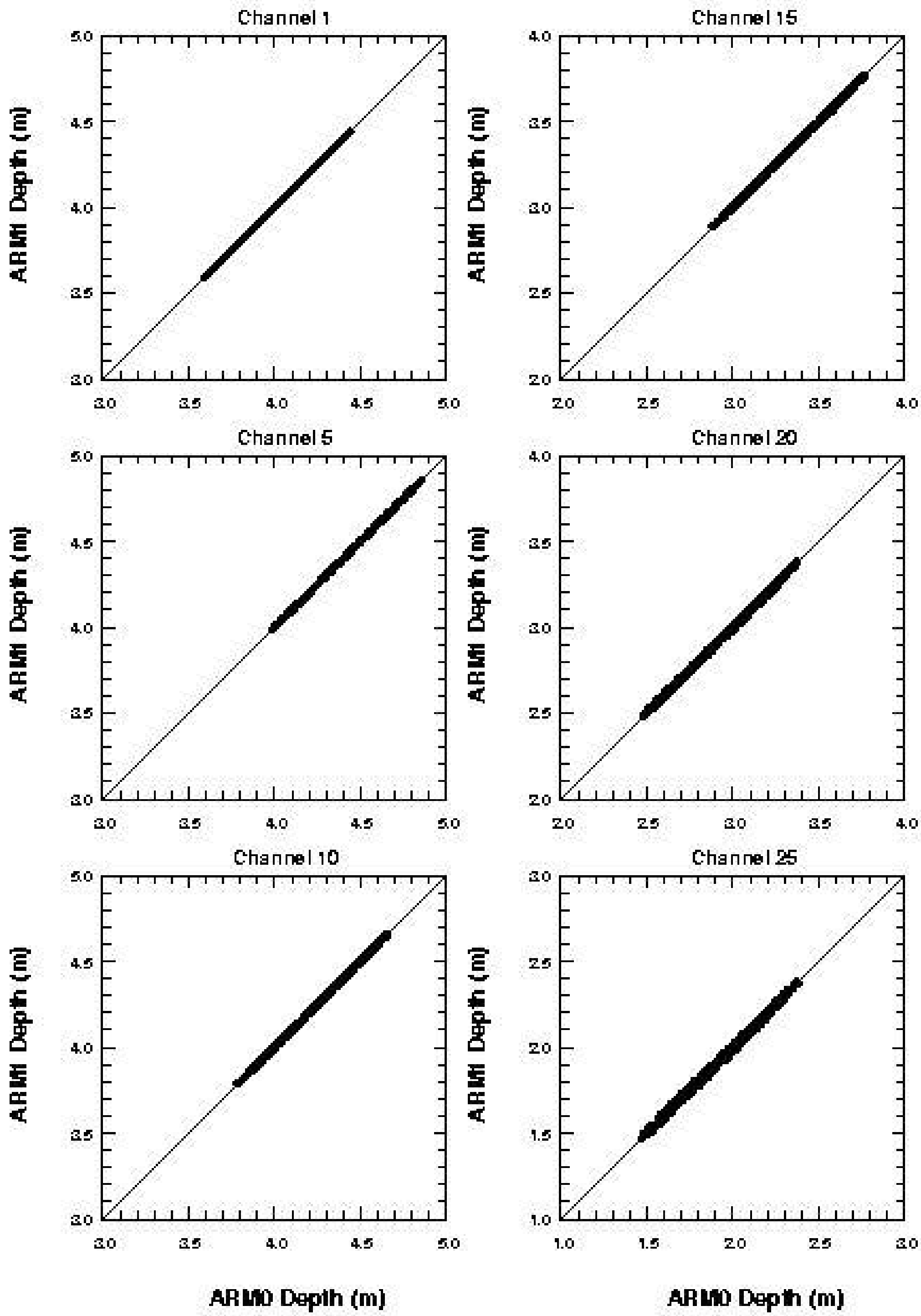


**Figure 3-10 Appoquinimink River Model DYNHYD5 Calibration Depth Comparisons**

### 3.4.2 Validation

Following calibration, the model was validated to the period between May 10 and July 25, 1991. As with the calibration period, flows, velocities and depths calculated by the ARM1 model over the validation period show agreement between the ARM1 and ARM0 models. Again the cross-plots of ARM0 and ARM1 DYNHYD5 model results are presented in Figure 3-11 through Figure 3-13 for velocity, flow and depth. The comparisons between the ARM1 and ARM0 model result in similar conclusions for the validation period as for the calibration period.

### 3.4.3 Tidally Averaged Transport

The tidally averaged transport from the ARM1 model during the calibration and validation period are presented in Figure 3-14 and Figure 3-15. In these figures the solid line represents the Appoquinimink River main stem, the dashed line represents Drawyer Creek and the dotted line represents Deep Creek. The tidally averaged flows ranged from 4 to 25 cfs with Drawyer Creek flow of approximately 14 cfs. Velocities ranged from approximately 5 to 45 cm/s with depths ranging from approximately 1 to 16 feet.

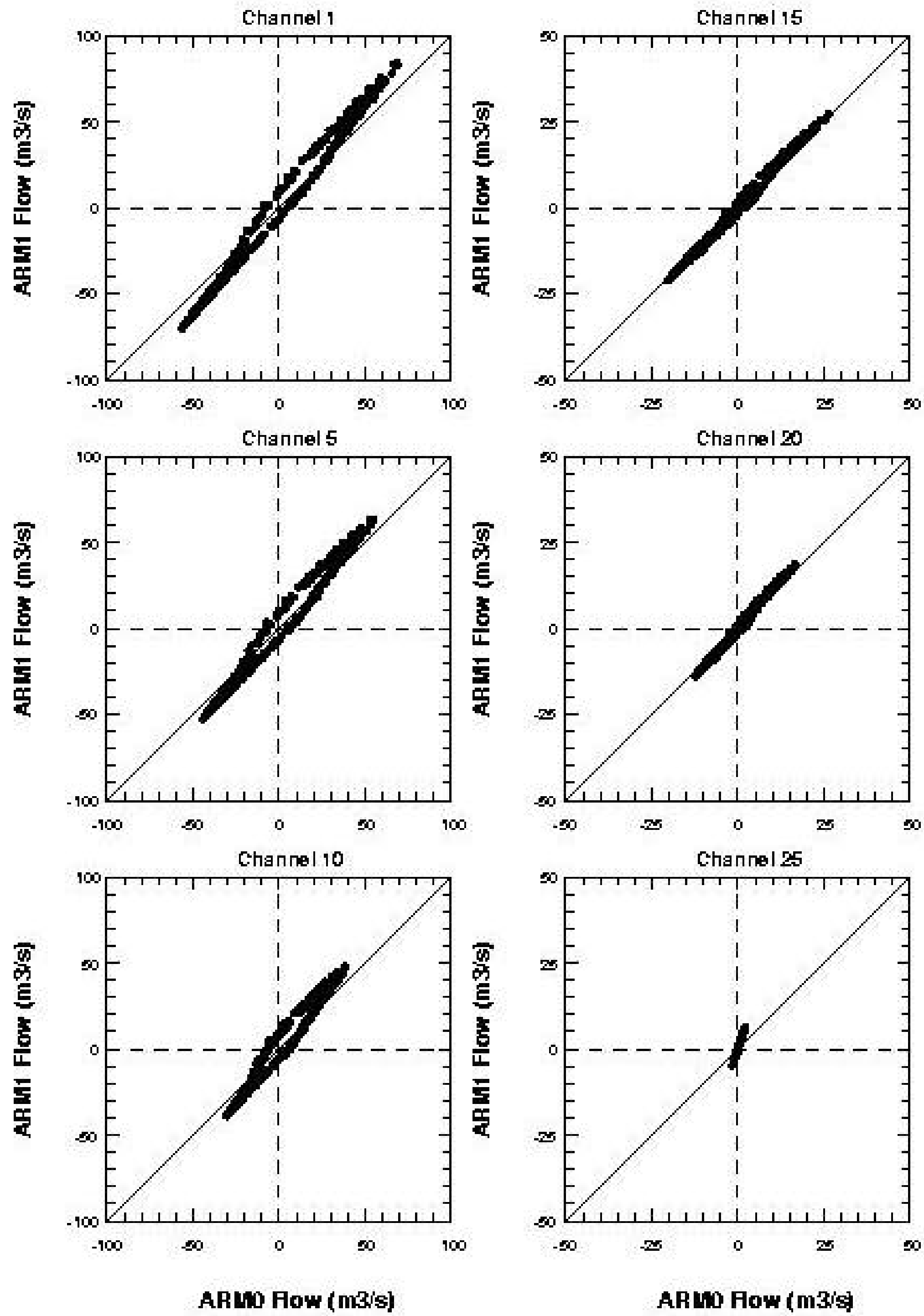


**Figure 3-11 Appoquinimink River Model DYNHYD5 Verification Flow Comparisons**

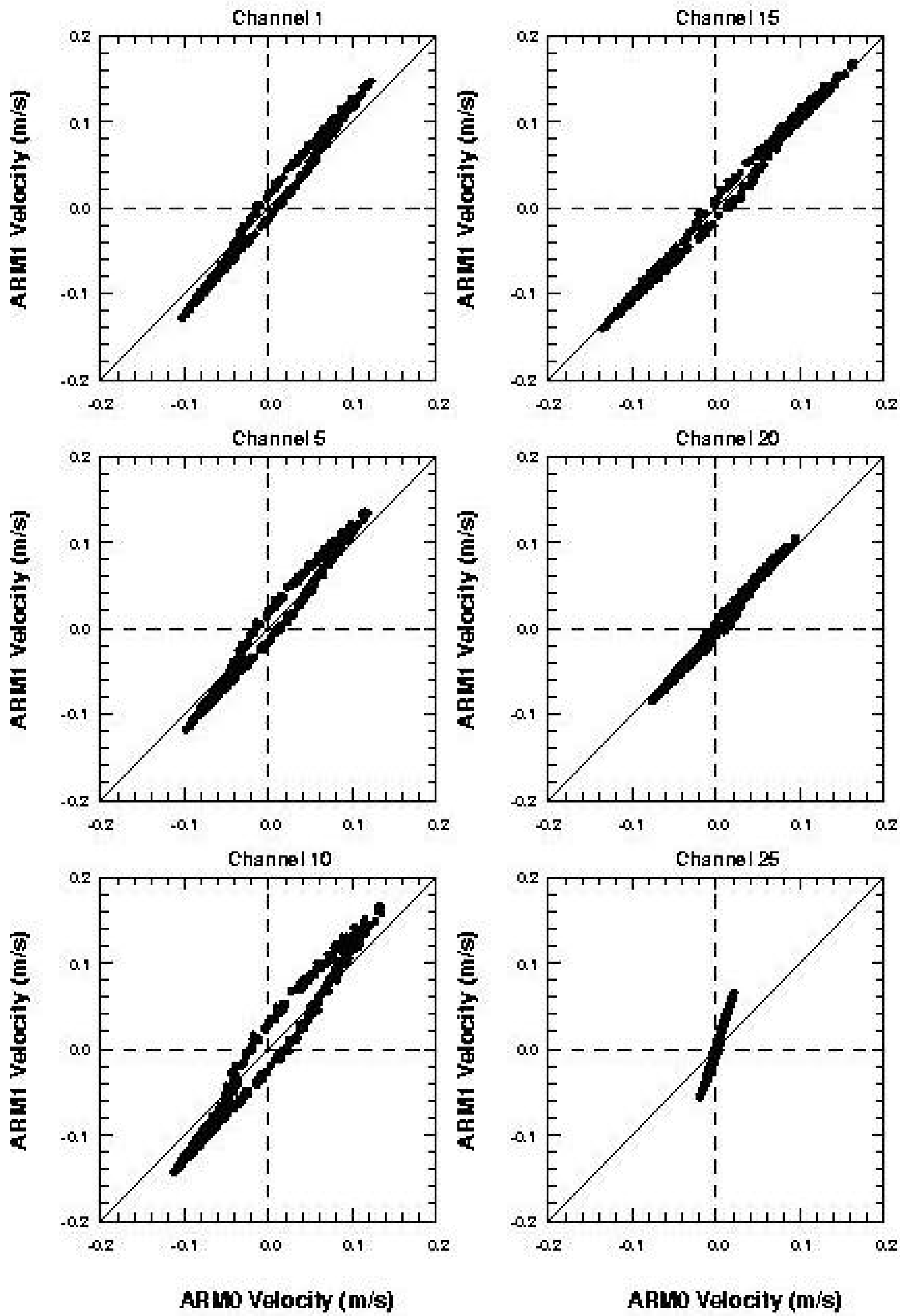


**Figure 3-12 Appoquinimink River Model DYNHYD5 Verification Velocity Comparisons**

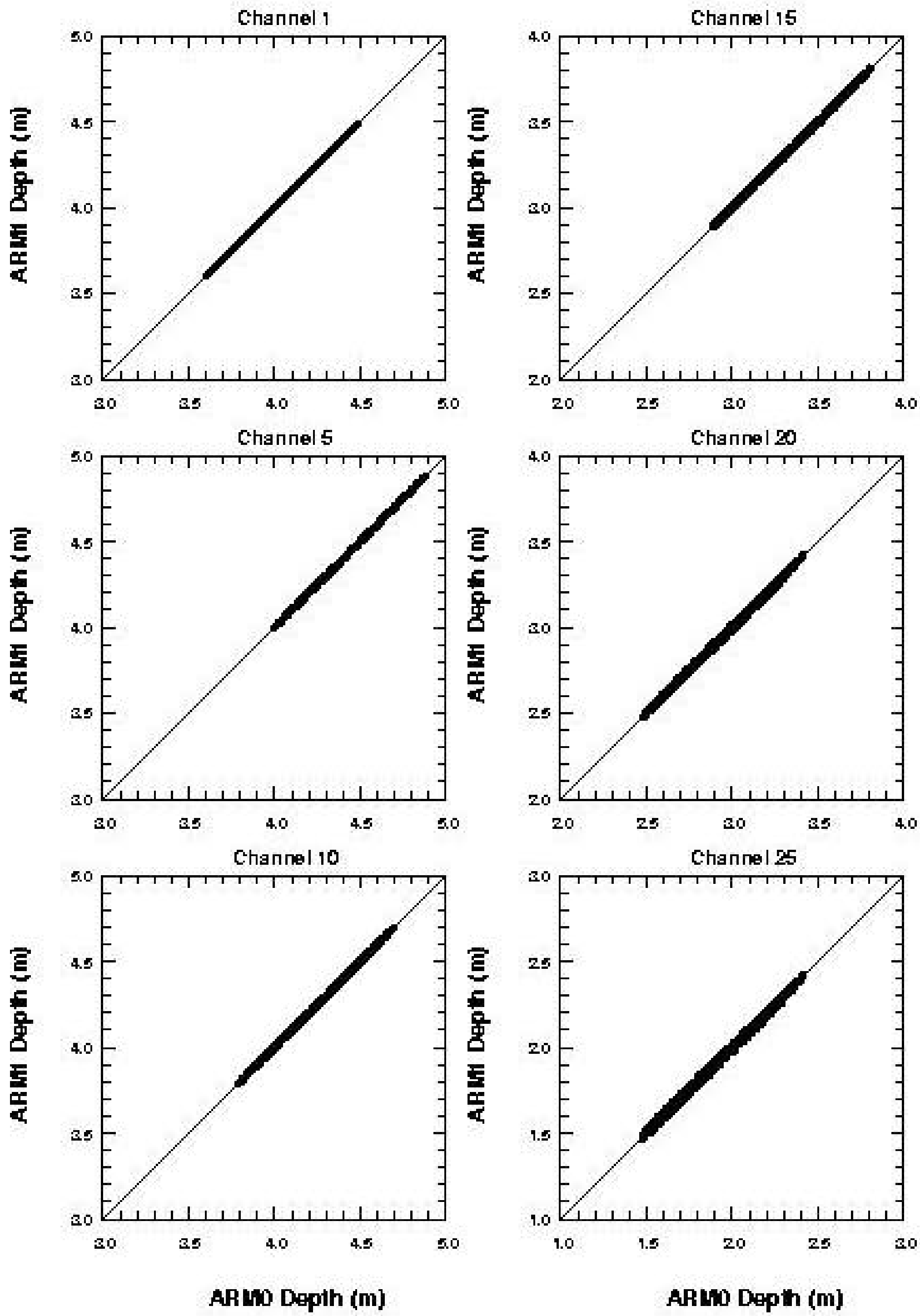


**Figure 3-13 Appoquinimink River Model DYNHYD5 Verification Depth Comparisons**

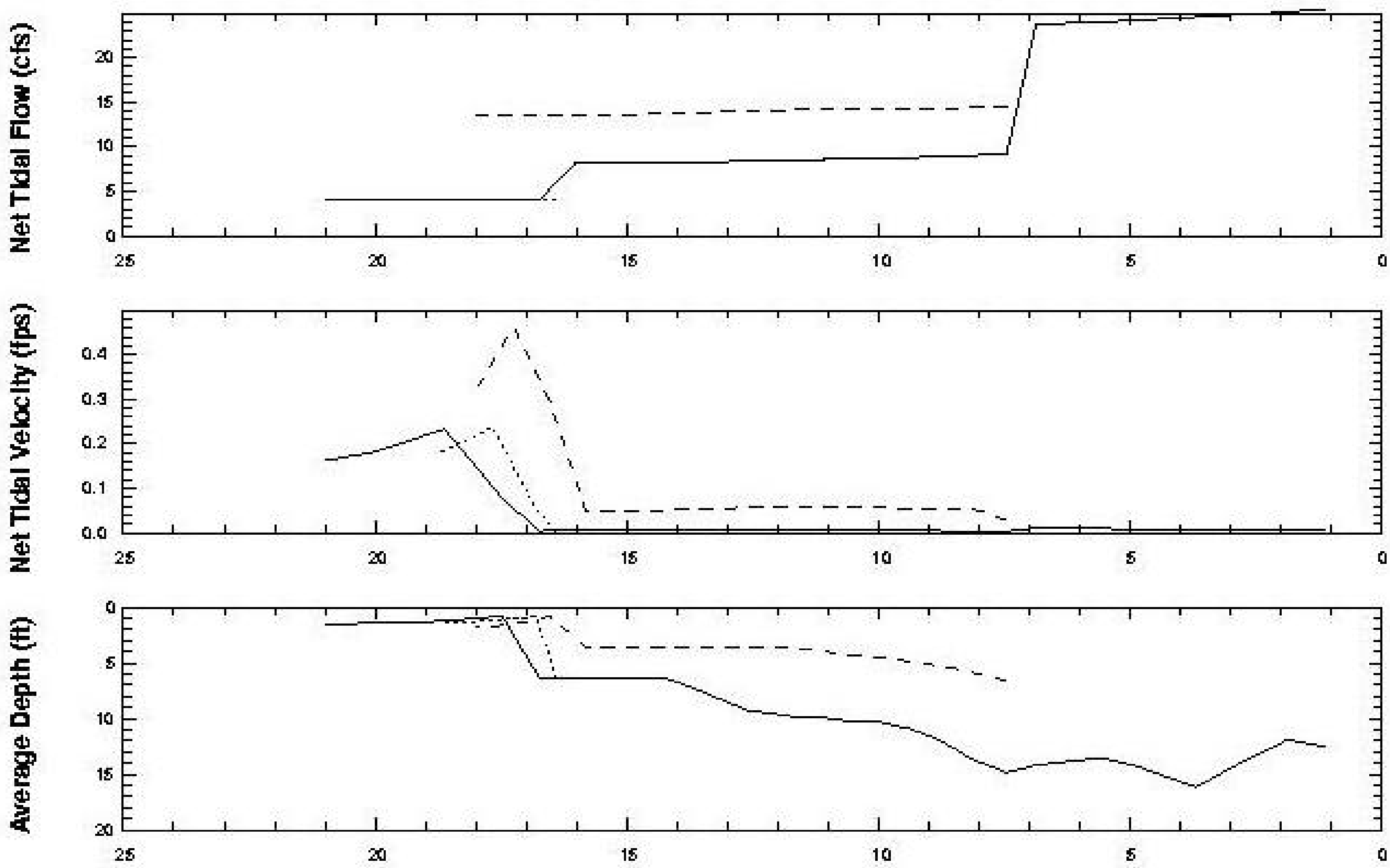


**Figure 3-14 Appoquinimink River Model DYNHYD5 Model Calibration Output (ARM1)**

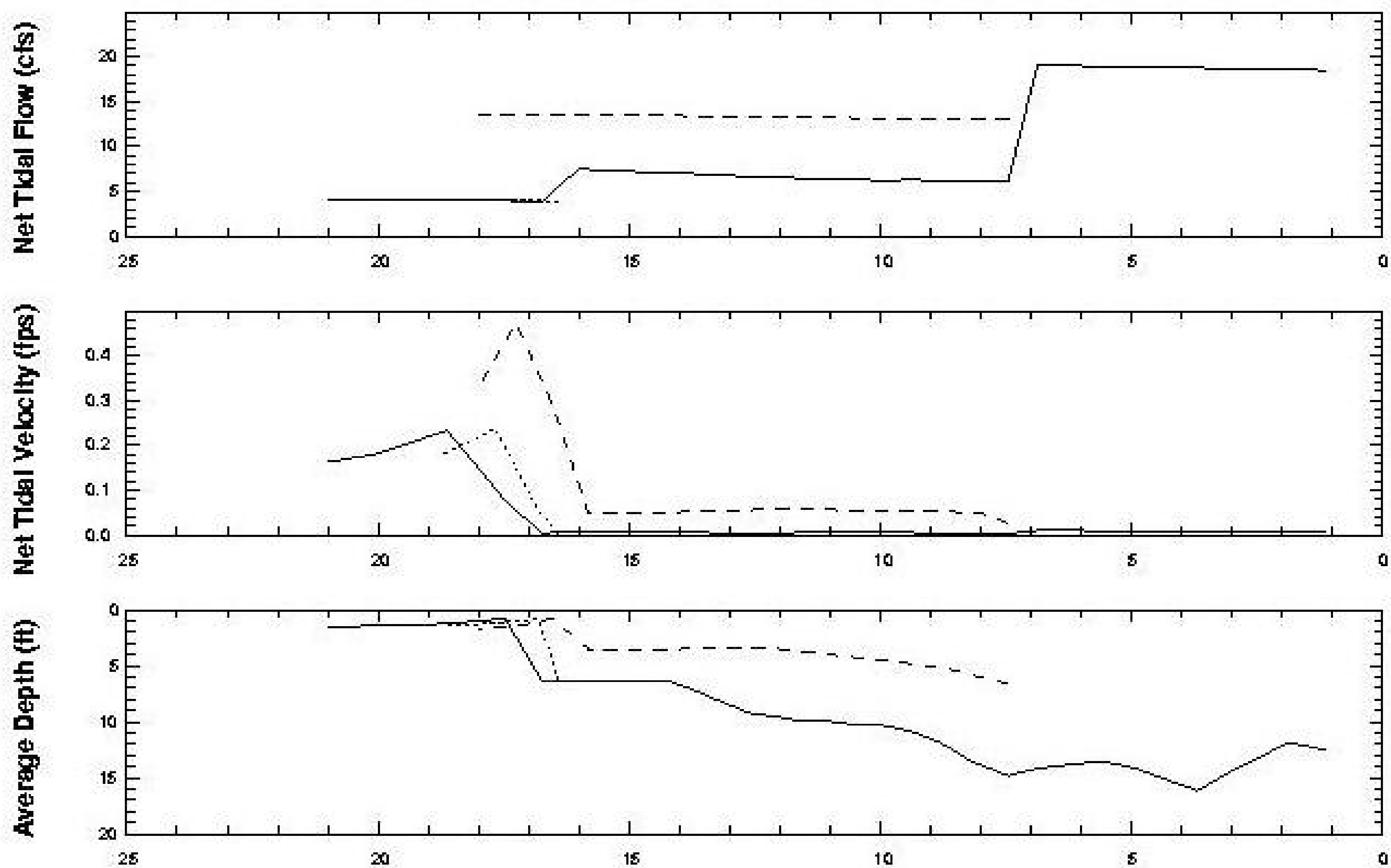


**Figure 3-15 Appoquinimink River Model DYNHYD5 Model Validation Output (ARM1)**

## 3.5. WASP5 Model Framework

### 3.5.1 Water Quality Modeling Framework (WASP-Eutro)

#### 3.5.1.1. Background

The Water Quality Analysis Simulation Program5 (WASP5) is an enhancement of the original WASP (DiToro et al., 1983; Connolly and Winfield, 1984; Ambrose, R.B. et al., 1988). This model allows users to interpret and predict water quality responses to natural phenomena and man-made pollution. WASP5 is a dynamic compartmental modeling program for aquatic systems, including both the water column and the underlying benthos. The time-varying processes of advection, dispersion, point and diffuse mass loading, and boundary exchange are represented in this program.

The WASP5 system consists of two standalone computer programs, DYNHYD5 and WASP5 that can be run in conjunction or separately. The hydrodynamic program, DYNHYD5, simulates the movement of water while the water quality program, WASP5, simulates the movement and interaction of pollutants within the water. For more information regarding DYNHYD5, please refer to Section 5.1.

WASP5 is a dynamic compartmental model that can be used to analyze a variety of water quality problems in such diverse water bodies as lakes, reservoirs, rivers, estuaries, and coastal waters. WASP5 is supplied with two kinetic sub-models to simulate two of the major classes of water quality problems: conventional pollutants (involving dissolved oxygen, biochemical oxygen demand (BOD), nutrients and eutrophication) and toxic pollutants (involving organic chemicals, metals, and sediment). The linkage of either sub-model with the WASP5 program results in the models EUTRO5 and TOXI5, respectively. The water quality model for the Appoquinimink River Watershed (ARM1) uses the EUTRO5 sub-model.

The equations solved by WASP5 are based on the principle of mass conservation. This principle requires that the mass of each water quality constituent being investigated must be accounted for. WASP5 traces each water quality constituent from the point of spatial and temporal input to its final point of export, conserving mass in space and time. To perform these mass balance computations, the user must supply WASP5 with input data defining seven important characteristics:

- Simulation and output control;
- Model segmentation;
- Advective and dispersive transport;
- Boundary conditions;
- Point and diffuse source waste loads;
- Kinetic parameters, constants, and time functions; and
- Initial conditions.

These input data, together with the general WASP5 mass balance equations and the specific chemical kinetics equations, uniquely define a special set of water quality equations. These are numerically integrated by WASP5 as the simulation proceeds in time. At user specified print intervals, WASP5 saves the values of all display variables for subsequent retrieval by the postprocessor program.

3.5.1.2. Theory and Equations

The water quality modeling framework used in this study and detailed in this report is based upon the principle of conservation of mass. The conservation of mass accounts for all of a material entering or leaving a body of water, transport of the material within the water body, and physical, chemical and biological transformations of the material. For an infinitesimal volume oriented along the axis of a three-dimensional coordinate system, a mathematical formulation for the conservation of mass may be written:

$$\frac{\partial c}{\partial t} = \underbrace{\frac{\partial}{\partial x}\left(E_x \frac{\partial c}{\partial x}\right) + \frac{\partial}{\partial y}\left(E_y \frac{\partial c}{\partial y}\right) + \frac{\partial}{\partial z}\left(E_z \frac{\partial c}{\partial z}\right)}_{\text{dispersive transport}} \underbrace{- U_x \frac{\partial c}{\partial x} - U_y \frac{\partial c}{\partial y} - U_z \frac{\partial c}{\partial z}}_{\text{advective transport}} \qquad (7\text{-}1)$$

where:

c = concentration of water quality variable [$M/L^3$];

t = time [T];

E = dispersion (mixing) coefficient due to tides and density and velocity gradients [$L^2/T$];

U = advective velocity [L/T];

$S_L$ = external inputs of the variable c [$M/L^3$-T];

$S_B$ = boundary loading rate (including upstream, downstream, benthic and atmospheric inputs) [$M/L^3$-T];

$S_K$ = sources and sinks of the water quality variable, representing kinetic interactions [$M/L^3$-T];

x,y,z = longitudinal, lateral and vertical coordinates; and

M,L,T = units of mass, length and time, respectively.

The model framework used in this study is comprised of three components:

1) Transport due to advective freshwater flow and density-driven tidal currents and dispersion;
2) Kinetics which control the physical, chemical and biological reactions being modeled (sources and sinks); and
3) External inputs entering the system (point sources, non-point sources and boundary conditions).

The transport within the Appoquinimink River Watershed System is a complex process affected by freshwater inflows, temperature, wind, and offshore forcing from the coastal shelf via the Delaware Bay. This transport was determined by the hydrodynamic model previously presented in Section 6. The hourly average fluxes from this hydrodynamic model were used to drive the transport field of the water quality model.

The kinetics represent the rates of reaction among water quality variables and approximate the physical, chemical and biological processes occurring in the Appoquinimink River Watershed. The kinetic framework of the water quality model is presented in Figure 3-16.

External inputs of carbonaceous biochemical oxygen demand (CBOD), nutrients (nitrogen and phosphorus) and other model variables are from point sources, non-point sources and model boundary conditions.

The modeling framework used in this study utilized the following state-variables:

1 - Ammonia Nitrogen ($NH_3$);
2 - Nitrate ($NO_3$);
3 - Dissolved Inorganic Phosphorus ($PO_4$);
4 - Phytoplankton (PHYT);
5 - Carbonaceous Biochemical Oxygen Demand (CBOD);
6 - Dissolved Oxygen (DO);
7 - Organic Nitrogen (Org N); and
8 - Particulate Organic Phosphorus (Org P).

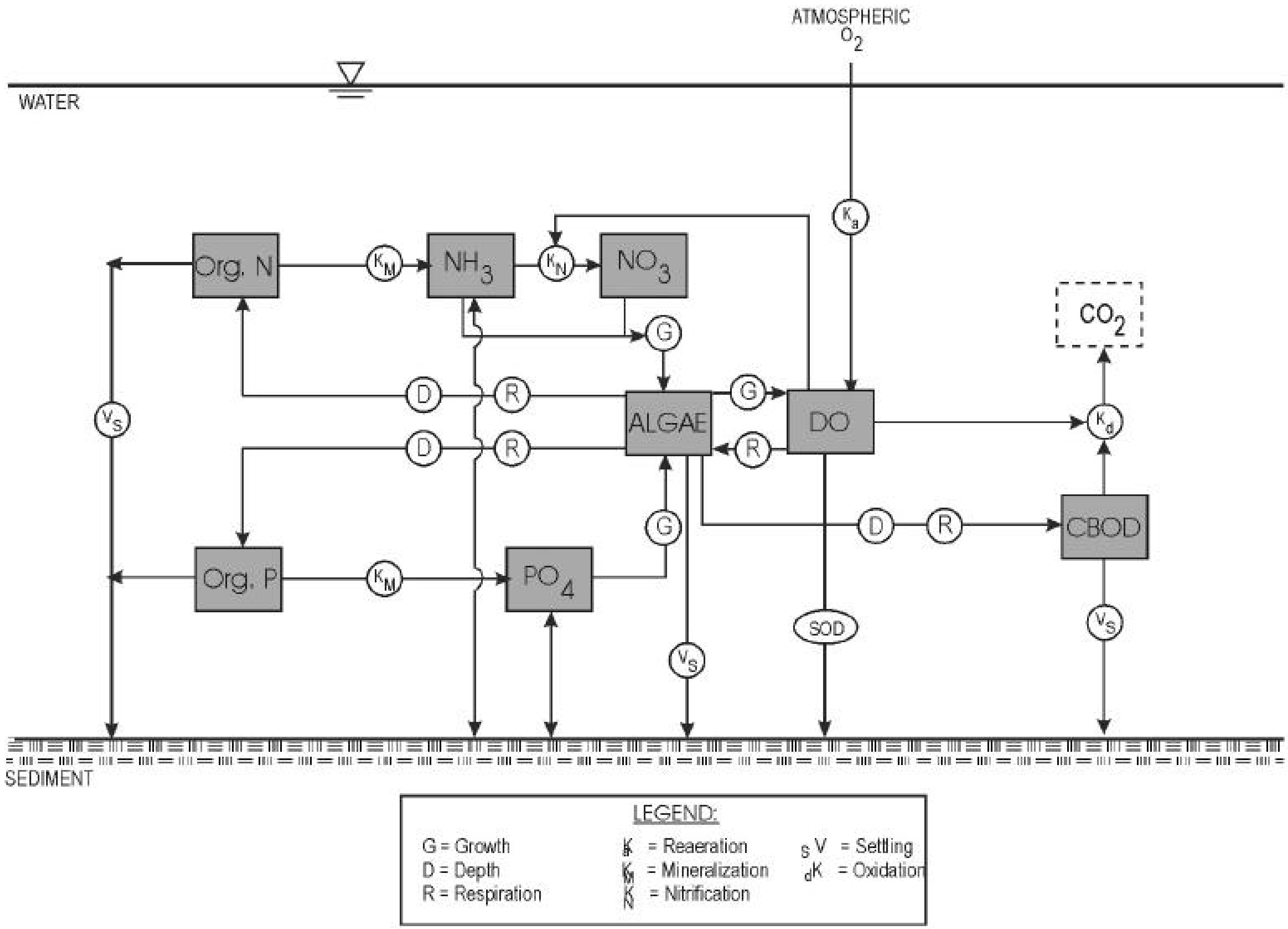


**Figure 3-16 WASP-EUTRO5 Water Quality Model Kinetic Framework for the Appoquinimink River Watershed**

3.5.2 Model Grid

The model segmentation for the Appoquinimink River Watershed water quality model is presented in Figure 7-2. The model is one-dimensional and consists of 47 water quality segments that average approximately one mile in length with one sediment segment for the entire model domain. The model segmentation is based on the DYNHYD5 model of the Appoquinimink River Watershed with the junctions used for water quality model segments. The original ARM0 water quality model improperly assigned the boundary condition segments in the model setup. It is necessary to assign the water quality boundary conditions one segment in from the DYNHYD5 boundary condition junctions. The proper assignment of water quality boundary condition segments was completed in the ARM1 WASP5 model. This improper assignment of boundary condition segments in the ARM0 model was noticed in the ARM1 model when the assigned boundary conditions were not properly affecting the internal model calculations.

## 3.6. WASP5 Model Calibration/Validation

The expanded WASP5 model (ARM1) calibration and validation results are compared to the results of the previous model (ARM0) and the data collected during the calibration period (August 11, 1991 to October 19, 1991) and validation period (May 10, 1991 to July 25, 1991). The model calibration and validation results for each parameter are presented in the following sections which show the data collected during each modeling period, the period average and range in model values calculated over that modeling period.

During this process it was noted that the WASP5 volumes used in the original ARM0 model did not correlate with the assigned lengths, widths and depths in the DYNHYD5 model. In order to be consistent between the DYNHYD5 and WASP5 models, re-calculated volumes were assigned in the new ARM1 WASP5 model based on the new DYNHYD5 model lengths, widths and depths.

3.6.1 Forcing Functions

Initial Conditions

Prior to the start of a model simulation, an initial condition was assigned to each segment for each of the eight systems (ON, $NH_3$, $NO_x$, OP, PO4, CBOD, DO, chl-a) being modeled. The initial conditions used for both modeling periods for the new model segments were based on the ARM0 model and expanded to the upstream reaches for Silver Lake, Noxontown Lake and Drawyer Creek.

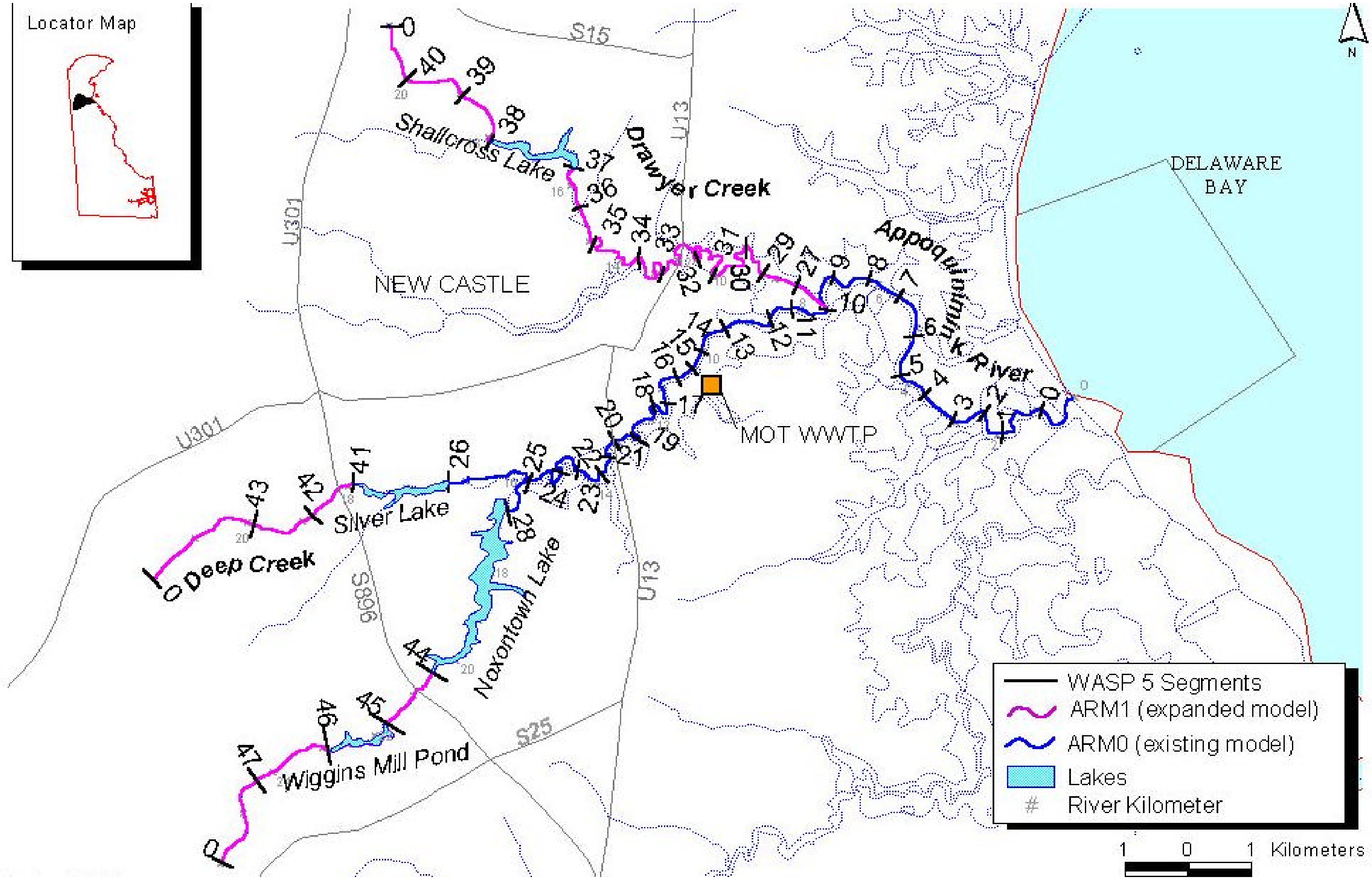


**Figure 3-17 WASP5 ARM1 Segments, Appoquinimink River Watershed**

Boundary Conditions

A total of four boundary conditions were accounted for in the model, including an open water boundary located at the Delaware Bay (segment 1) which is driven by the tidal conditions in the Bay. The three other boundaries are upstream freshwater inputs for Drawyer Creek (segment 40), Deep Creek (segment 43) and main stem Appoquinimink River (segment 47). The freshwater inputs are constant flows and are not affected by tidal conditions in the lower Appoquinimink River.

No data was available on the modeled periods for the new model segments. At the upstream boundary locations, the boundary conditions used in the ARM0 model were used for the boundary concentrations in the ARM1 model.

3.6.2 Pollutant Loading

Point Source Loads

One municipal point source is located in the Appoquinimink River Watershed, the Middletown-Odessa-Townsed WWTP, which discharges approximately 0.5 MGD. This point source, was previously included in the ARM0 model and the daily loading values used are listed in Table 3-4.

**Table 3-4 Point Source Loads**

| Parameter | Load (kg/d) |
|---|---|
| $NH_3$ | 18.9 |
| $NO_3$+$NO_2$ | 0 |
| $PO_4$ | 1.6 |
| Chl-a | 0 |
| $CBOD_5$ | 36.9 |
| DO | 1.3 |
| ON | 9.5 |
| OP | 4.8 |

Only daily average data was available to assign loads for the New Castle County WWTP and by using constant values, uncertainty in the actual daily load is incorporated into the model calculation.

3.6.3 Calibration Period

The model-data comparisons for the calibration period are presented in Figure 3-18. The data are shown as the filled symbols (average and range) and the average main stem Appoquinimink River model results during the calibration period are presented as a solid line with the shaded region representing the range calculated during the period. The data for the Drawyer Creek period average model output is presented as the dashed line while the dotted line represents the Deep Creek model output. Model (ARM1) and data comparisons are presented for organic nitrogen (Org N), ammonia nitrogen ($NH_3$), nitrite plus nitrate nitrogen ($NO_2$+$NO_3$), organic phosphorus (Org P), orthophosphate ($PO_4$), carbonaceous BOD (CBOD), dissolved oxygen (DO) and chlorophyll “a”. Overall the model reasonably reproduces the available field data in the Appoquinimink River main stem for all parameters. No data was available for Drawyer Creek and Deep Creek during the modeled time period making it impossible to compare the model results to the observed data.

Due to the improper boundary condition assignment and WASP5 volume inconsistencies between the DYNHYD5 model lengths, width and depths in the original ARM0 model, more weight was placed on reproducing the observed water quality data rather than the original ARM0 model output. An example of the ARM1 versus ARM0 model outputs is presented in Figure 3-19. The ARM0 model results are shown in blue and the ARM1 model results in red. Reasonable agreement between the ARM1 and ARM0 model outputs is obtained.

### 3.6.4 Validation Period

The results of the model validation are presented in Figure 3-20 and Figure 3-21 in the same format as the calibration figures. Again, the ARM1 model reasonably reproduces the observed data for the Appoquinimink River main stem. Data were not available for comparison in the expanded areas of the model.

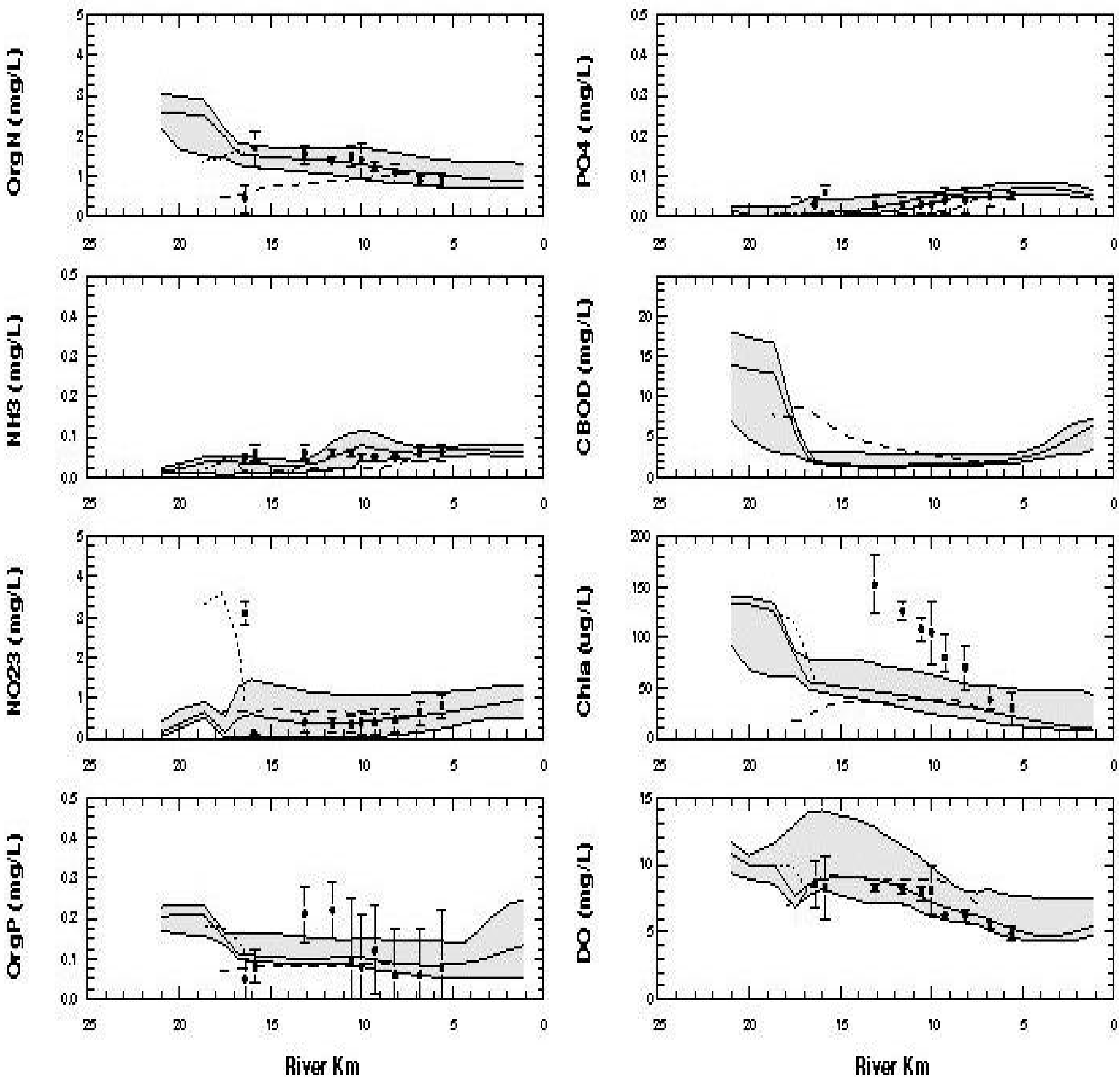


**Figure 3-18 Appoquinimink River Model Calibration Output (ARM1)**

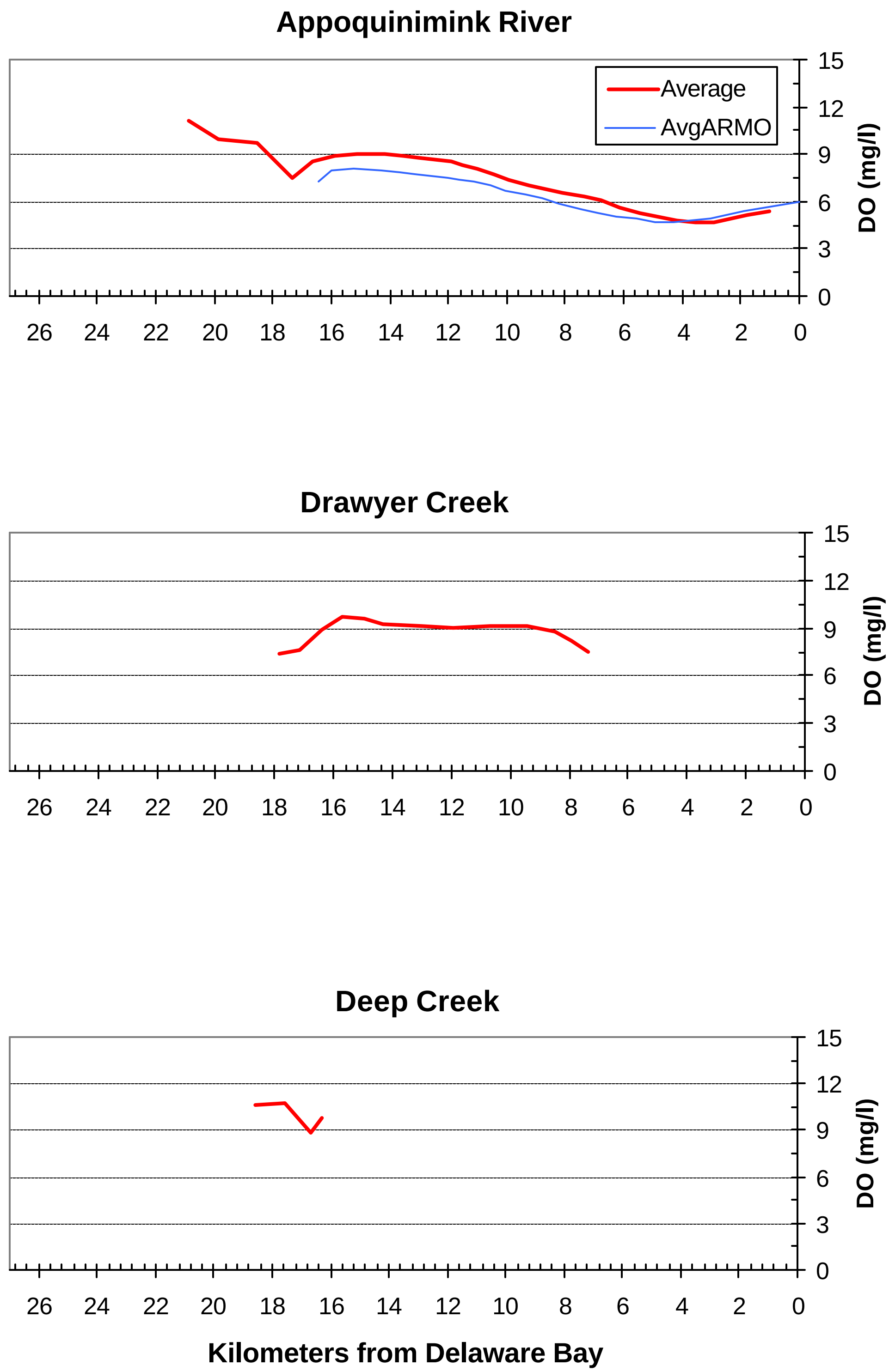


**Figure 3-19 Average DO ARM0 Versus ARM1, Calibration Period**

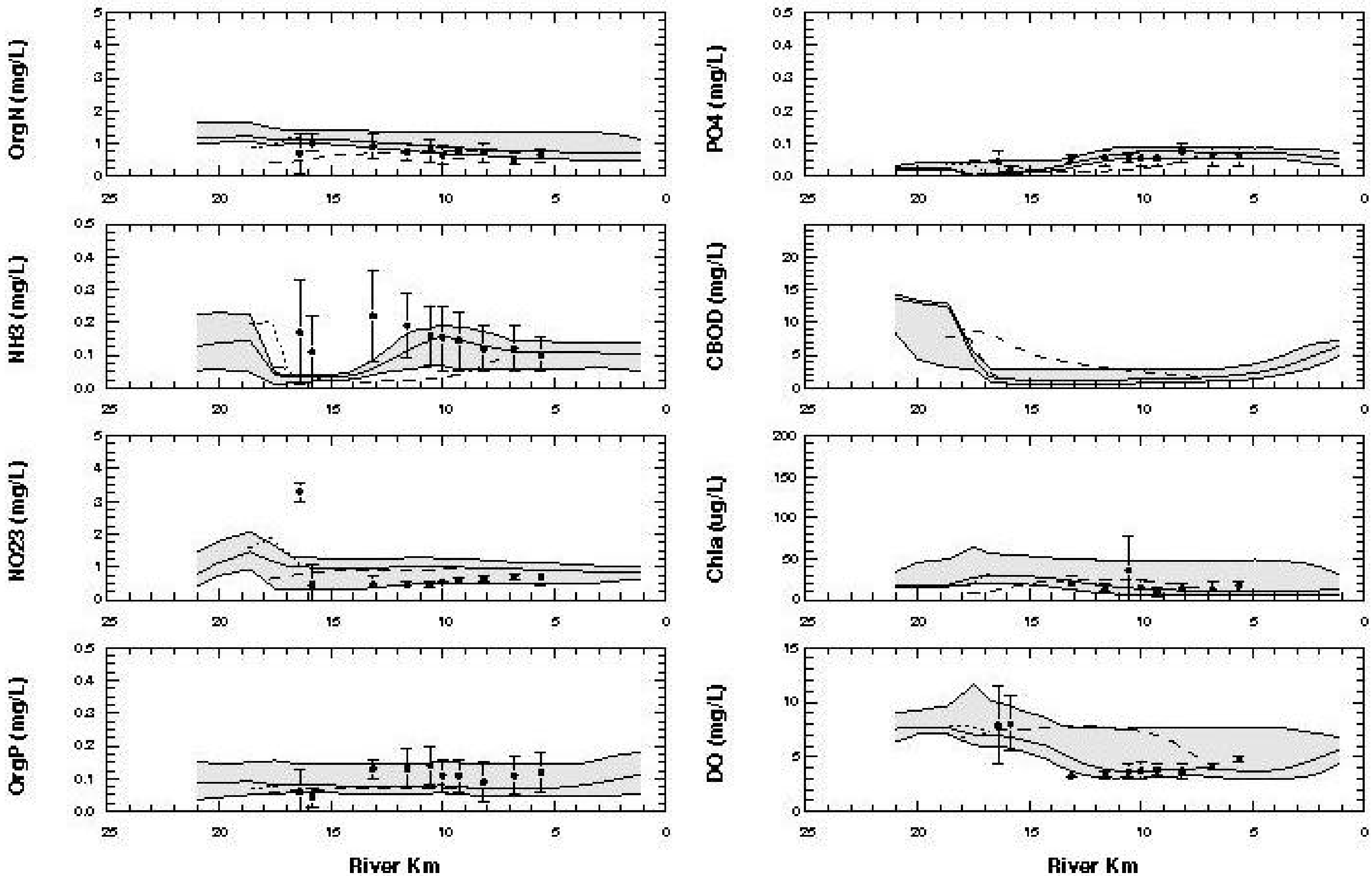


**Figure 3-20 Appoquinimink River Model Verification Output (ARM1)**

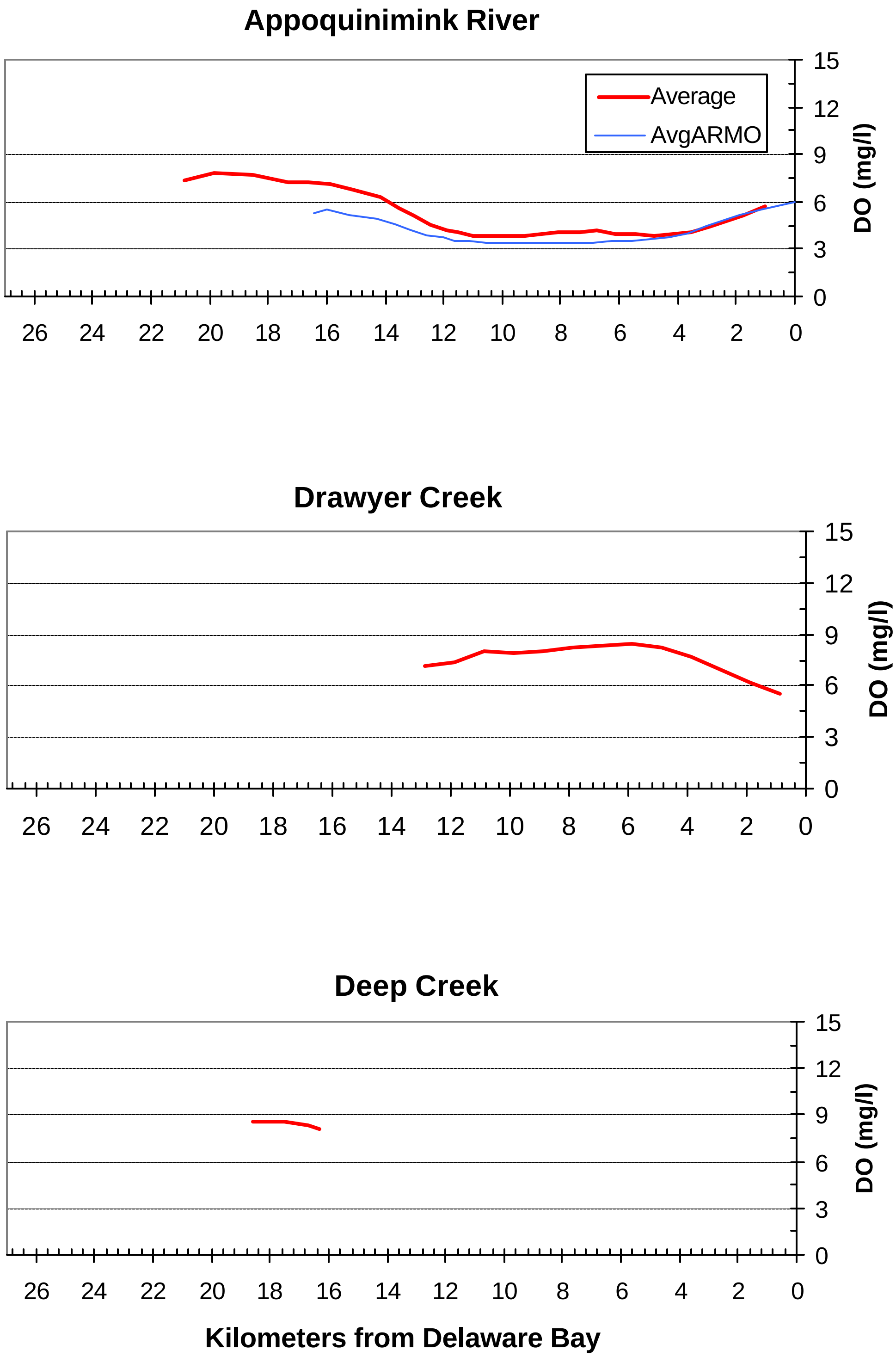


**Figure 3-21 Average DO ARM0 Versus ARM1, Verification Period**

# 4. Adjusting ARM1 to Reflect Current Conditions

Recent water quality data was compiled at a number of stations in the Appoquinimink River watershed. This data comes from 17 DNREC monitoring stations (Figure 4-1) as presented below.

- 109091 – Mouth of Appoquinimink River to Delaware Bay;
- 109121 – Appoquinimink River at Route 9 Bridge;
- 109141 – Appoquinimink River at mouth of East Branch Drawyer Creek;
- 109151 – Appoquinimink River above West Branch Drawyer Creek;
- 109051 – Appoquinimink River at Route 299 Bridge (Odessa);
- 109171 – Appoquinimink River west bank from MOT WWTP;
- 109041 – Appoquinimink River at Route 13 Bridge;
- 109131 – Noxontown Pond Overflow (Road 38);
- 109221 – Downstream from Wiggins Mill Pond at Route 71;
- 109231 – Upstream from Wiggins Mill Pond at Grears Corner Road;
- 109071 – Drawyer Creek at Route 13;
- 109191 – Shallcross Lake Overflow;
- 109211 – Drawyer Creek above Shallcross Lake at Cedar Lane Road;
- 109201 – Tributary to Drawyer Creek at Marl Pit Road;
- 109031 – Silver Lake Overflow;
- 109241 – Deep Creek at DE Route 15;
- 109251 – Deep Creek above Silver Lake at Route 71;

This recent data set was used to assess the model results in Drawyer Creek, Deep Creek and the upstream Appoquinimink River areas that were added into the ARM1 model (1991 data). In general, the recent Drawyer Creek data (Stations 109071, 109191 and 109211) for nutrients, chlorophyll-a, BOD and DO is reasonably represented by the ARM1 model. Differences can be due to a number of factors such as river flow, tidal forcing, NPS loads, meteorology, change in land use, pollution control strategies, etc.. The same conclusions can be drawn for Deep Creek (Stations 109031, 109241 and 109251) and the upstream Appoquinimink River (Stations 109131, 109221 and 109231) areas. Figure 4-2 illustrates the average values for the total N, total P, DO, and $CBOD_5$ values for the time period prior to 1997 versus the values obtained between 1997 through 2000. The red symbols indicate the concentrations at each station prior to 1997 and the blue symbols reflect the 1997 through 2000 concentrations. It is clear that the average total N concentrations have decreased while the average total P concentrations have increased between these two time periods. With the exception of one station, the average N values all fall below the 3.0 mg/L concentration (maximum target criteria). In contrast, over half of the stations report average total P values higher than 0.2 mg/L (maximum target criteria). The DO and $CBOD_5$ levels are relatively consistent. Figure 4-3 illustrates the '97-'00 data with the inclusion of the minimum and maximum values at each station. In addition, the symbols are color coded to indicate which segment they are located on: blue for the Appoquinimink River, pink for Deep Creek, green for Drawyer Creek and red for station 109201 located on a tributary off of Drawyer Creek. Although the minimum daily average standard for DO (5.5 mg/L) is met, the minimum (4 mg/L) is not. The daily averages for nutrients fall within the targets (1-3 mg N/L, 0.1-0.2mg P/L) but there are maximum values over 400% greater than those ranges. The highest concentrations of total P are in Drawyer Creek while the highest total N concentrations are found in Deep Creek. The lowest levels of DO are in the Appoquinimink River.

To better reflect the current conditions this data was incorporated into the ARM1 model. Prior to the integration of this new data, a sensitivity analysis was performed to evaluate the effect of changing the variables and parameters defined within the model. Table 4-1 reflects the effect of changing model parameters on the total N, total P, CBOD, Chl-a, and DO. The concentration changes listed reflect the average concentration change within all the waters modeled in the watershed. By evaluating the responses to changes in the parameters, e.g. increasing SOD causes DO to decline, it was determined that the inclusion of the 1997-2000 data would not harm the integrity of the ARM1 model while providing a better picture of the current conditions and a more meaningful baseline to simulate load reductions scenarios. Detailed graphs displaying each scenario are included in Appendix A.

Station 109201 (Marl Pit Rd.) data reflected a high P concentration that was not included in the ARM0 model. Because of its high P levels and drainage from the Middletown area in which significant development is occurring, the boundary condition flow and nutrient load for the Drawyer was adjusted to incorporate this tributary. A constant flow input (0.080 $m^3/s$) at section 34 was added and the flow at section 42 was reduced from 0.381 $m^3/s$ to 0.301 $m^3/s$. The corresponding nutrient load was added into the NPS auxiliary input file.

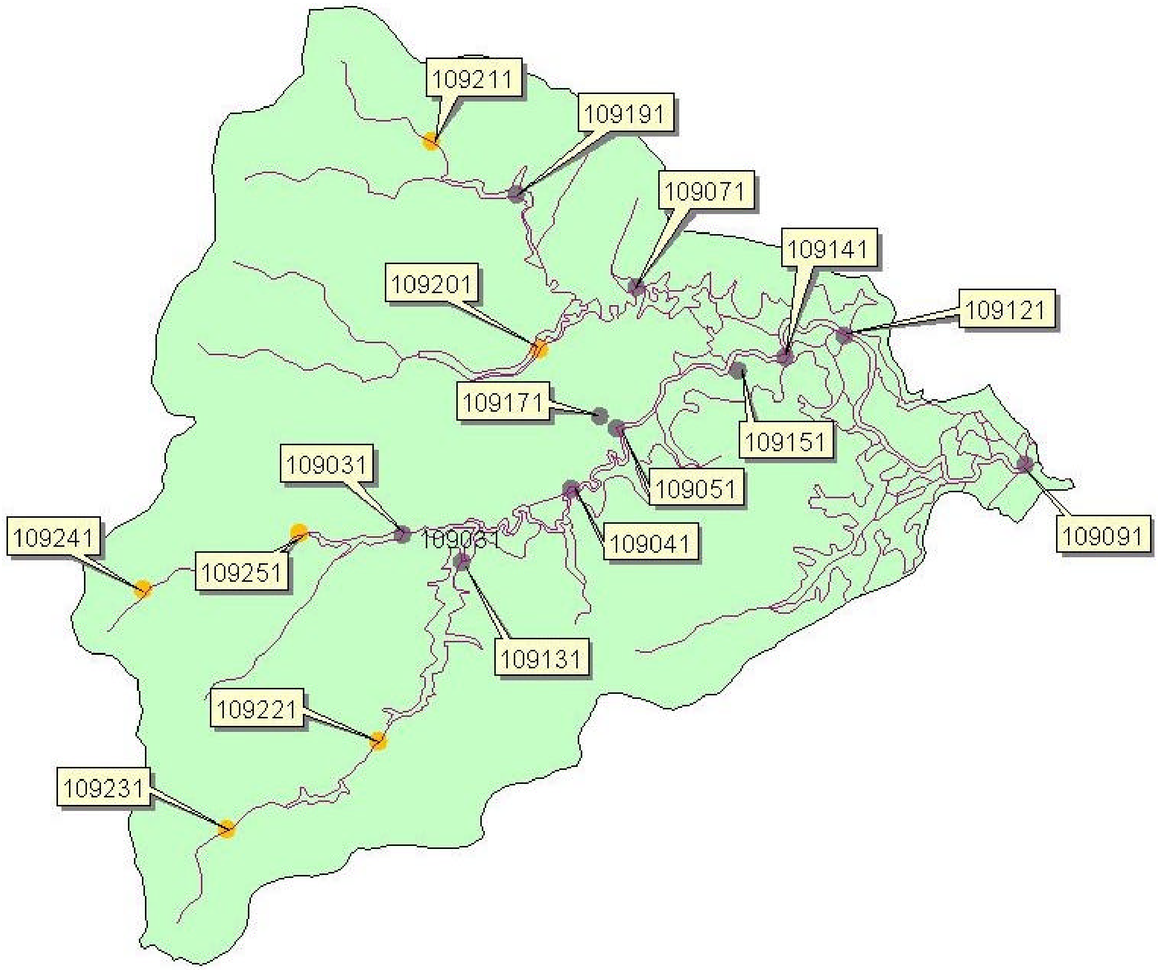


**Figure 4-1 Monitoring Stations within the Appoquinimink River Watershed**

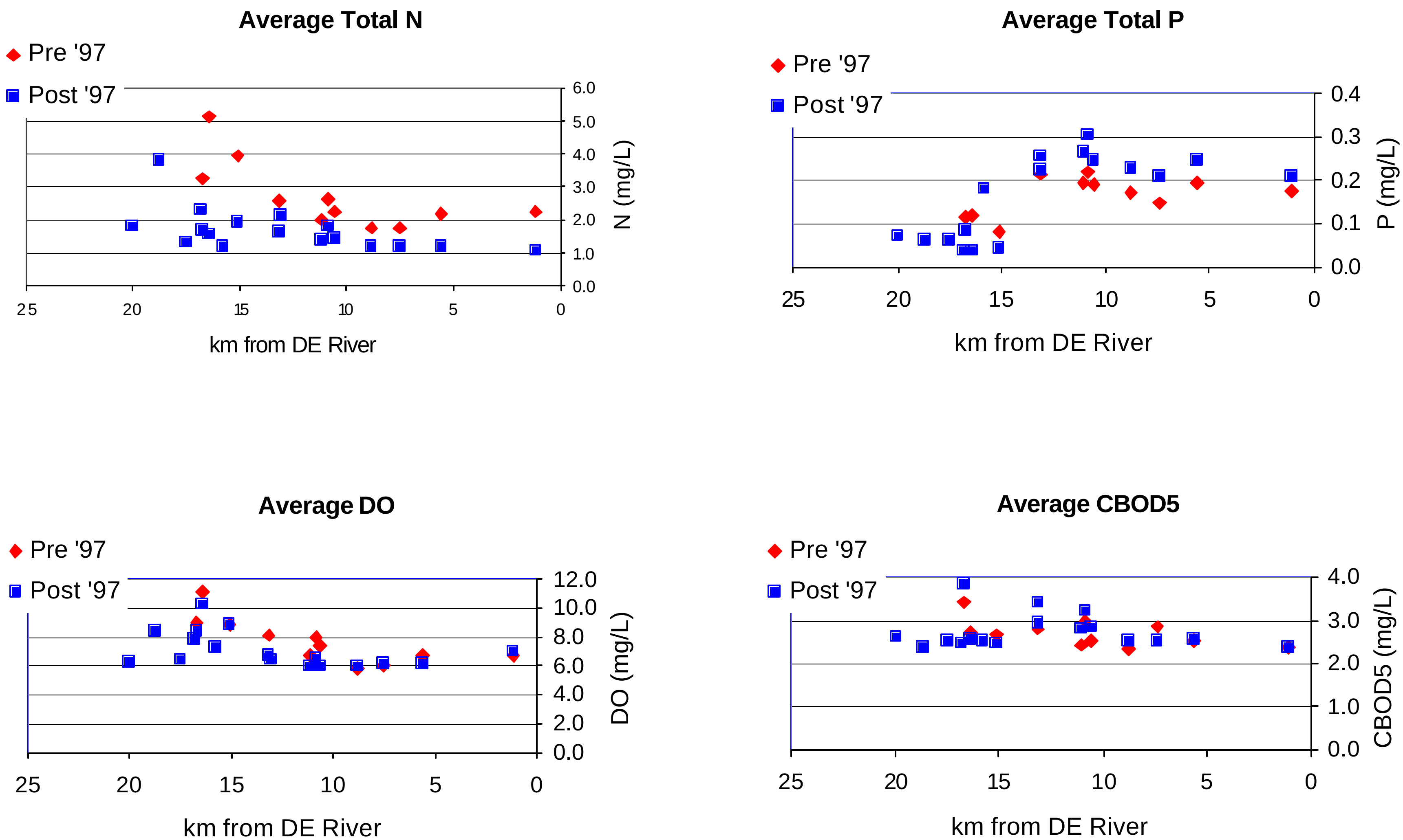


**Figure 4-2 Comparison of Pre 1997 Data versus 1997-2000 Data for the Appoquinimink Watershed**

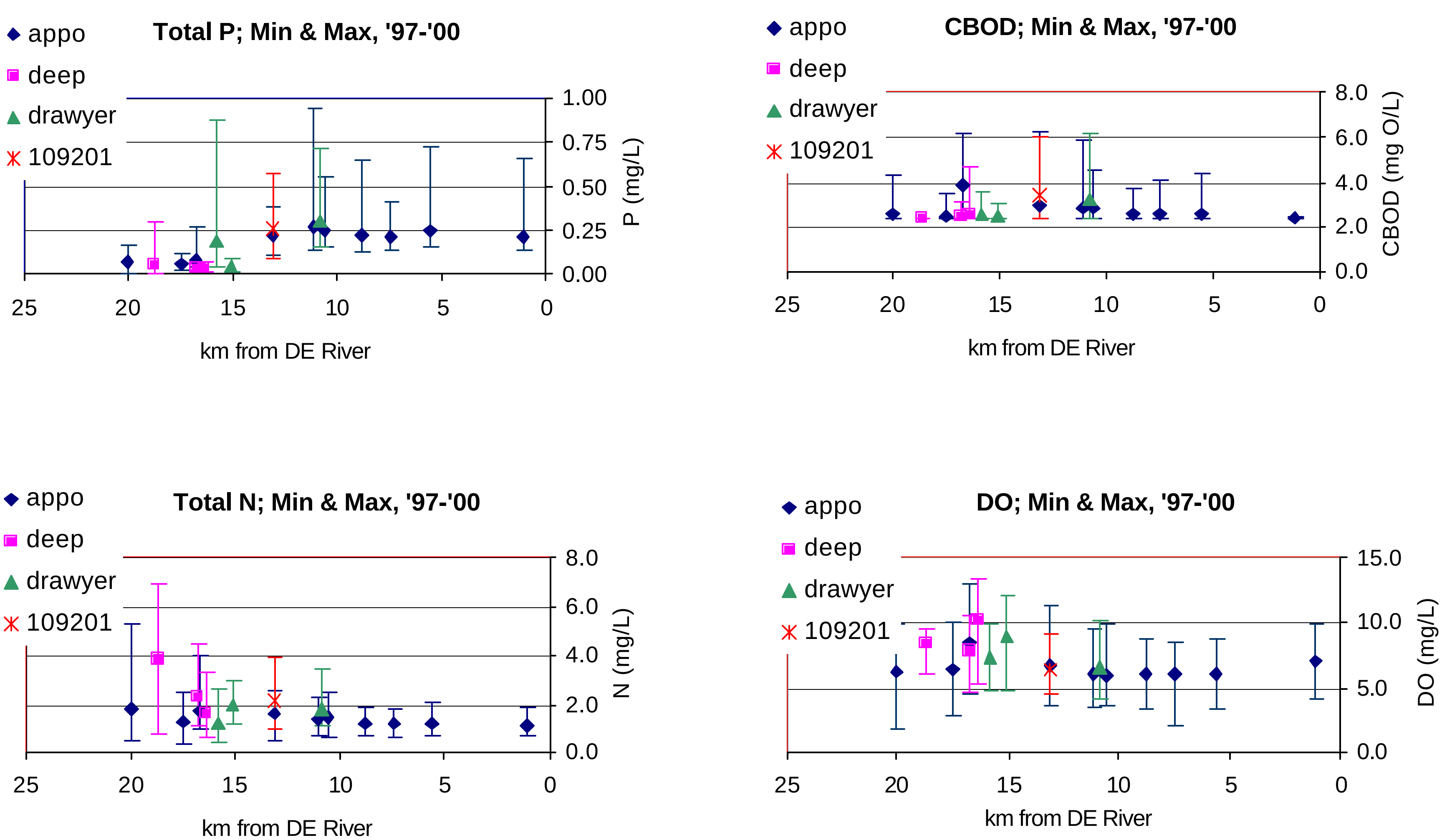


**Figure 4-3 Max Min Values for the 1997-2000 Data**

Table 4-1 Sensitivity Analysis Scenarios C1-C52

| Scenario | Parameter Changed | Effect | | | | |
|---|---|---|---|---|---|---|
| | | Minimum DO mg/L | (average concentration change with respect to waspver4 run) | | | |
| | | | Total N mg/L | Total P mg/L | CBOD mg/L | Chl-a mg/L |
| C1 | No PS MOT | 4.04 | -0.0500 | -0.0087 | -0.1071 | -0.6361 |
| C2 | ½ X $FNH_4$ | 3.83 | 0 | 0 | 0 | 0 |
| C3 | ½ X SOD1D | 4.52 | -0.0003 | 0 | -0.0162 | 0 |
| C4 | 2X SOD1D | 0.74 | -0.0033 | 0 | 0.0945 | 0 |
| C5 | 2X $FNH_4$ | 3.83 | 0 | 0 | 0 | 0 |
| C6 | ½ X $FPO_4$ | 3.83 | 0 | 0 | 0 | 0 |
| C7 | 2X $FPO_4$ | 3.83 | 0 | 0 | 0 | 0 |
| C8 | ½ X SAL | 3.90 | 0 | 0 | -0.0014 | 0 |
| C9 | 2X SAL | 3.70 | 0.0001 | 0 | 0.0029 | 0 |
| C10 | ½ X KESG | 5.43 | 0.0754 | 0.0086 | 0.1107 | 9.0396 |
| C11 | 2X KESG | 2.99 | -0.0410 | -0.0032 | -0.0907 | -5.8927 |
| C12 | 0 constant inflow | | | unstable | | |
| C13 | ½ X constant inflow | 3.83 | 0.0127 | 0.0019 | -0.1267 | 0.2555 |

| Scenario | Parameter Changed | Effect | | | | |
|---|---|---|---|---|---|---|
| | | Minimum DO mg/L | (average concentration change with respect to waspver4 run) | | | |
| | | | Total N mg/L | Total P mg/L | CBOD mg/L | Chl-a mg/L |
| C14 | 1½ X constant inflow | 3.80 | -0.0128 | -0.0018 | 0.1293 | 0.2530 |
| C15 | 2X constant inflow | | | unstable | | |
| C16 | ½ X Flow, all segments | 3.71 | 0.2225 | 0.0127 | 0.0724 | 3.6237 |
| C17 | 2X Flow, all segments | 3.85 | -0.2363 | -0.0168 | -0.0994 | -4.6343 |
| C18 | BC: ½ X NH3-N | 3.85 | -0.0222 | 0 | -0.0003 | 0 |
| C19 | BC: 2X NH3-N | 3.80 | 0.0457 | 0 | 0.0007 | 0 |
| C20 | Added MOT inflow | 3.81 | -0.0050 | -0.0004 | -0.0082 | -0.0628 |
| C21 | C20 & BC: ½ X NOx-N | 3.81 | -0.0653 | -0.0004 | -0.0037 | -0.0628 |
| C22 | C20 & BC: 2X NOx-N | 3.82 | 0.1165 | -0.0004 | -0.0171 | -0.0628 |
| C23 | C20 & BC: ½ X PO4 | 3.81 | -0.0117 | -0.0043 | -0.0186 | -0.7591 |
| C24 | C20 & BC: 2X PO4 | 3.82 | 0.0075 | 0.0074 | 0.0101 | 1.1404 |
| C25 | C20 & BC: ½ X Phyt | 3.89 | -0.0396 | -0.0035 | -0.0375 | -2.6253 |
| C26 | C20 & BC: 2X Phyt | 3.60 | 0.0614 | 0.0069 | 0.0466 | 4.7211 |

| Scenario | Parameter Changed | Effect | | | | |
|---|---|---|---|---|---|---|
| | | Minimum DO mg/L | (average concentration change with respect to waspver4 run) | | | |
| | | | Total N mg/L | Total P mg/L | CBOD mg/L | Chl-a mg/L |
| C27 | C20 & BC: ½ X CBOD | 4.15 | -0.0053 | -0.0004 | -1.3075 | -0.0628 |
| C28 | C20 & BC: 2X CBOD | 2.50 | -0.0042 | -0.0004 | 2.6614 | -0.0628 |
| C29 | C20 & BC: ½ X Diss O2 | 2.67 | -0.0043 | -0.0004 | 0.0313 | -0.0628 |
| C30 | C20 & BC: 10 mg/L Diss O2 | 4.00 | -0.0055 | -0.0004 | -0.0292 | -0.0628 |
| C31 | C20 & BC: ½ X Org-N | 3.82 | -0.1518 | -0.0004 | -0.0082 | -0.0628 |
| C32 | C20 & BC: 2X Org-N | 3.79 | 0.2829 | -0.0004 | -0.0081 | -0.0628 |
| C33 | C20 & BC: ½ X Org-P | 3.78 | -0.0117 | -0.0224 | -0.0181 | -0.7307 |
| C34 | C20 & BC: 2X Org-P | 3.86 | 0.0086 | 0.0434 | 0.110 | 1.2355 |
| C35 | C20 & 7Q10, New permit MOT PS | 3.95 | -0.0340 | -0.0063 | -0.1747 | -0.4657 |
| C36 | C35 & SOD values: EPA TMDL 1/98 | 4.76 | -0.0340 | -0.0063 | -0.1925 | -0.4657 |
| C37 | C36 & 15kg/day CBOD NPS | 4.76 | -0.0340 | -0.0063 | -0.1798 | -0.4657 |
| C38 | C37 & EPA DO BC, DE river | 4.90 | -0.0340 | -0.0063 | -0.1821 | -0.4657 |
| C39 | C38 & EPA initial DO conc | 4.68 | -0.0340 | -0.0063 | -0.1769 | -0.4657 |

| Scenario | Parameter Changed | Effect | | | | |
|---|---|---|---|---|---|---|
| | | Minimum DO mg/L | (average concentration change with respect to waspver4 run) | | | |
| | | | Total N mg/L | Total P mg/L | CBOD mg/L | Chl-a mg/L |
| C40 | C39 & EPA '98 TMDL BC, DE River: NH3-N | 4.60 | 0.0074 | -0.0063 | -0.1763 | -0.4657 |
| C41 | C40 & EPA '98 TMDL BC, DE River: NOx-N | 4.60 | 0.1032 | -0.0063 | -0.1816 | -0.4657 |
| C42 | C41 & EPA '98 TMDL BC, DE River: PO4 | 4.62 | 0.1053 | -0.0004 | -0.1783 | -0.2060 |
| C43 | C42 & EPA '98 TMDL BC, DE River: Phyt | 4.30 | 0.1575 | 0.0054 | -0.1416 | 3.7242 |
| C44 | C43 & EPA '98 TMDL BC, DE River: CBOD | 2.83 | 0.1581 | 0.0054 | 2.0851 | 3.7242 |
| C45 | C44 & EPA '98 TMDL BC, DE River: Org-N | 2.82 | 0.4229 | 0.0054 | 2.0857 | 3.7242 |
| C46 | C45 & EPA '98 TMDL BC, DE River: Org-P | 2.83 | 0.4288 | 0.0455 | 2.0941 | 4.3146 |
| C47 | C46 & EPA '98 TMDL Group G | 2.84 | 0.4268 | 0.0453 | 2.0907 | 4.1495 |
| C48 | C47 & EPA '98 TMDL initial NOx conc | 2.84 | 0.4337 | 0.0453 | 2.0901 | 4.1495 |
| C49 | C48 & EPA '98 TMDL initial Phyt conc | 3.11 | 0.3692 | 0.0390 | 2.0120 | 0.5417 |
| C50 | C49 & EPA '98 TMDL initial CBOD conc | 2.87 | 0.3692 | 0.0390 | 2.3626 | 0.5417 |
| C51 | C50 & EPA '98 TMDL initial Org-N conc | 2.87 | 0.3481 | 0.0390 | 2.3626 | 0.5417 |
| C52 | C51 & EPA '98 TMDL initial Org-P conc | 2.87 | 0.3501 | 0.0432 | 2.3661 | 0.7371 |

# 5. Evaluation of Various Loading Scenarios and Proposed TMDL

The results of the water quality monitoring and modeling show that the State water quality standards and targets with regard to DO, total N and total P are not met in several segments of the Appoquinimink River and it's tributaries. Therefore, reduction of pollutant loads from point and/or nonpoint sources are necessary to achieve water quality standards and targets.

To determine the optimum load-reduction scenario, the ARM1 model was adjusted to the current conditions and used as a baseline to evaluate different reduction scenarios. Table 5-1 illustrates the incorporation of the current conditions into the ARM1 model in order to develop a baseline to evaluate possible load reduction scenarios. The final baseline deviates from the original ARM1 hydver4.inp in the following ways: the updated hydver4 includes a 0.5 mgd flow from the MOT, the flow is reduced from the headwater of the Drawyer (originally 0.380 $m^3/s$, new 0.301 $m^3/s$), and a 0.80 $m^3/S$ flow now enters the Drawyer at section 34. Deviations from the original ARM1 waspver4.inp include the incorporation of boundary conditions reflecting the monitoring station data taken between 1997 and 2000 (SOD, chl-a, CBOD, DO, $NH_3$, $NO_x$, ON, OP, PO4, and temperature). The new boundary condition data was incorporated individually into the runs (D series) using C38 as an initial starting point (see Appendix B for detailed scenario results). In addition to the scenarios reported, the effect of the reduction scenarios using the ARM0 model as well as unreported scenarios were also evaluated.

The baseline scenario and final reduction scenario are illustrated in Figure 5-1. The solid lines represent the Average concentrations on Julian day 199 and the dotted lines represent the corresponding baseline concentrations in the Appoquinimink River, Drawyer Creek, and Deep Creek. The final scenario brings both the total P and total N nutrient levels into compliance with DNREC's target levels and meets the State water quality standard for DO. To achieve this the proposed TMDL holds the MOT nutrient and $CBOD_5$ discharge levels constant at the concentrations prescribed by the 1998 EPA TMDL. In addition, the non point source reductions include a 20% reduction in $PO_4$, OP, ON, $NH_3$, and $NO_x$ along with an 18.4% decrease in SOD. Since the flux rates of nutrients and SOD is a function of pollutant loads received by the system, it is a reasonable assumption to relate the percentage of the rate change to the percentage of load change (similar mechanism was suggested by the Army Corps of Engineers for the Inland Bays Model). The algorithm for this change can be shown as:

$$\text{Adjusted Rate} = \text{Base Rate}\,(1 + PSR * PSF + NPSR * NPSF)$$

Where:

Base Rate = the nutrient and flux rates used in model calibration
PSR = percent change of point source load change. The PSR is positive when the load is increased and is negative when load is decreased
PSF = fraction of total load represented by point sources
NPSR = percent change of nonpoint source load change. The NPSR is positive when the load is increased and is negative when load is decreased
NPSF = fraction of total load represented by nonpoint sources

**Table 5-1 Current Condition and Baseline Development Scenarios**

| Scenario | Scenario Description |
|---|---|
| D1 | C38 |
| D2 | D1 with no NPS: auxilary |
| D3 | D1 with no NPS: Appo, Deep & Drawyer |
| D4 | D1 with no NPS |
| D5 | D1 with no NPS or MOT |
| D6 | D1 with no nutrient load from DE River |
| D7 | D1 with no nutrient load or chl-a from DE River |
| D8 | D1 with oxygen addition in NPS auxilary |
| D9 | D1 with '98 EPA TMDL 7Q10 flows |
| D10 | D1 with '97-'00 $NH_3$, $NO_X$, ON data for DE River BCs |
| D11 | D10 with '97-'00 chl-a data for DE River BCs |
| D12 | D11 with '97-'00 $CBOD_5$ data for DE River BCs |
| D13 | D12 with '97-'00 OP & PO4 data for DE River BCs |
| D14 | D13 with '97-'00 dissolved oxygen data for DE River BCs |
| D15 | D14 with DE River BC: 10% nutrient load reduction, 10% increase in DO |
| D16 | D14 with KESG=3.2 in segments 1-14 (secchi depth 24") |
| D17 | D16 with DE River BC: 20% total load reduction & 20% increase in DO |
| D18 | D17 with NPS: Appo, Deep, Drawyer 20% total load reduction |
| D19 | D1 with '97-'00 data, all BCs |
| D20 | D19 with no NPS: auxilary |
| D21 | D19 with no NPS: Appo, Deep & Drawyer |
| D22 | D19 with no MOT |
| D23 | D19 with no NPS |
| D24 | D19 with no NPS or MOT |
| D25 | D19 with DE River BC: 10% nutrient load reduction, 10% increase in DO |
| D26 | D19 with DE River BC: 10% increase in DO |
| D27 | D19 with 25% NPS: Appo, Deep & Drawyer total load reduction |
| D28 | D27 with 10% SOD reduction |
| D29 | D19 with 25% NPS total load reduction & 10% SOD reduction |
| D30 | D19 with 35% NPS total load reduction & 10% SOD reduction |
| D31 | D29 with '98 EPA TMDL DE River DO BC |
| D32 | D31 with 50% decrease in $PO_4$ & OP into the Drawyer |
| D33 | D32 with DE River BC: 10% total load reduction |
| D34 | D32 with '98 EPA TMDL DE River BCs |
| D35 | D32 with 15% SOD decrease instead of 10% SOD decrease |
| D36 | D32 with 25% SOD decrease instead of 10% SOD decrease |
| D37 | D36 with '98 EPA TMDL 7Q10 |

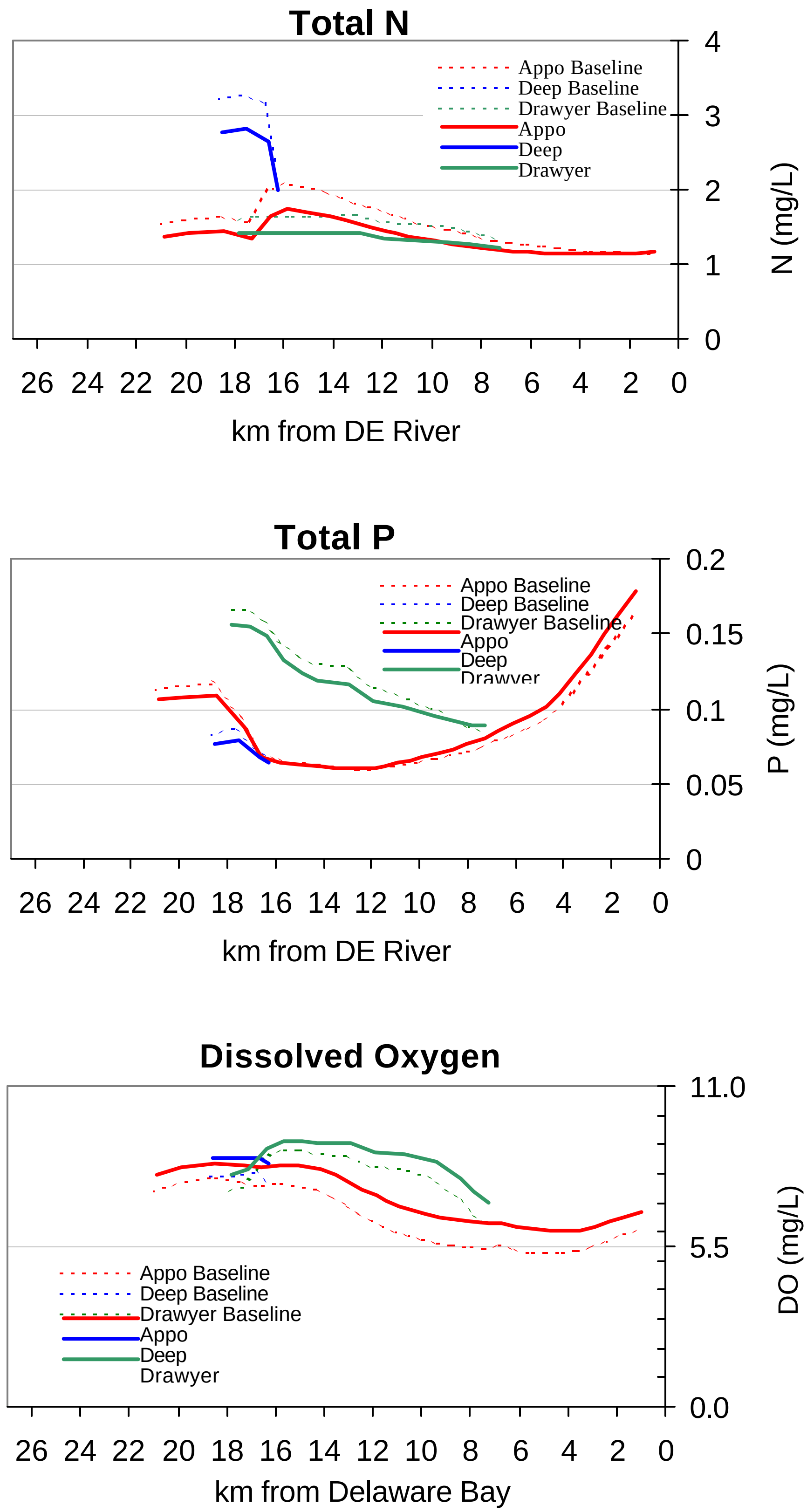


**Figure 5-1 Base Line versus Final TMDL Reduction Scenario, Average Values on Day 199**

Table 5-2 illustrates the proposed TMDL loads for the Appoquinimink River Watershed. The only point source (MOT) will be limited to a discharge of 10.4 lb total N per day, 2.1 lb. total P per day, and 34.8 lb $CBOD_5$ per day with a flow rate not to exceed 0.5 mgd. The proposed nonpoint source loads are 334.1 lb total N per day and 18.0 total P per day. The total TMDL loads are 344.5 lb total N per day, 20.1 lb total P per day, and 34.8 lb $CBOD_5$ per day.

**Table 5-2 Proposed TMDL Loads for the Appoquinimink Watershed**

| Source | Flow (mgd) | Total N (lb/d) | Total P (lb/d) | CBOD5 (lb/d) |
|---|---|---|---|---|
| Waste Load Allocation (WLA) for Point Source: MOT | 0.5 | 10.4 | 2.1 | 34.8 |
| Load Allocation (LA) for Nonpoint Sources | - | 334.1 | 18.0 | - |
| Proposed TMDL Total Loads | - | 344.5 | 20.1 | 34.8 |

# 6. Discussion of Regulatory Requirements for TMDLs

Federal regulations at 40 CFR Section 130 require that TMDLs must meet the following eight minimum regulatory requirements:

1. The TMDLs must be designed to achieve applicable water quality standards
2. The TMDLs must include a total allowable load as well as individual waste load allocations for point sources and load allocations for nonpoint sources
3. The TMDLs must consider the impact of background pollutants
4. The TMDL must consider critical environmental conditions
5. The TMDLs must consider seasonal variations
6. The TMDLs must include a margin of safety
7. The TMDLs must have been subject to public participation
8. There should be a reasonable assurance that the TMDLs can be met

***1. The Proposed Appoquinimink River Watershed TMDL is designed to achieve applicable water quality standards.***

The model analysis indicates that after the proposed reductions are met, the minimum DO level in any portion of the Appoquinimink will not fall below the 5.5 mg/L standard.

With regard to nutrients, model analysis indicates that the target levels (1.0-3.0 mg/L total N, 0.1-0.2 mg/L total P) will be obtained after the proposed reductions are met.

***2. The Proposed Appoquinimink River Watershed TMDL includes a total allowable load as well as individual waste load allocations for point sources and load allocations for nonpoint sources.***

Table 5-2 lists the proposed WLA and LA for the Appoquinimink River Watershed. The total WLA is 10.4 lb/d total N, 2.1 lb/day total P, and 34.8 lb/d $CBOD_5$. The LA is 334.1 lb/d total N and 18.0 lb/d total P.

***3. The proposed Appoquinimink River TMDL considers the impact of background pollutants.***

The proposed TMDL is based upon a calibrated and verified hydrodynamic and water quality model of the Appoquinimink River and its tributaries, lakes, and ponds. The model was developed using an extensive water quality and hydrological database. The water quality and hydrological database included headwater streams representing background conditions for nutrients and other pollutants. Therefore, it can be concluded that the impact of background pollutants are considered in the proposed Appoquinimink River Watershed TMDL.

### *4. The proposed Appoquinimink River Watershed TMDL considers critical environmental conditions*

The proposed TMDL was established based on the calculated 7Q10 (Section 3) and the ambient conditions on Julian day 199 when the ambient air and water temperatures are relatively high. The average salinity in the section of the Appoquinimink River between the confluence of the Delaware River and the intersection with Drawer Creek is above the salt water salinity standard of 5 ppt. but because the minimum is below the 5 ppt level, it is considered fresh water. The results of the water quality modeling analysis have shown that considering the above design conditions, State water quality standards and targets are still meet within the Appoquinimink River Watershed. Therefore, it can be concluded that consideration of critical environmental conditions was incorporated in the Appoquinimink River Watershed TMDL analysis.

### *5. The proposed Appoquinimink River Watershed TMDL considers seasonal variations.*

The model used to represent the watershed was calibrated for the period of August 11 through October 14, 1991 and was validated for the period of May 10 through July 25, 1991. The above calibration and verification periods included different seasons with varying environmental conditions. Therefore, it can be concluded that consideration of seasonal variations was incorporated in the Appoquinimink River Watershed TMDL analysis.

### *6. The proposed Appoquinimink River Watershed TMDL considers a margin of Safety.*

EPA's technical guidance allows consideration of a margin of safety as implicit or as explicit. An implicit margin of safety is when conservative assumptions are considered for model development and TMDL establishment. An explicit margin of safety is when a specified percentage of assimilative capacity is kept unassigned to account for uncertainties, lack of sufficient data, or future growth.

An implicit margin of safety has been considered for establishing the proposed Appoquinimink River Watershed TMDL. The ARM1 model is calibrated using conservative assumptions regarding reaction rates, pollutant loads, and other environmental conditions. Consideration of these conservative assumptions contributes to the implicit margin of safety. In addition, the proposed TMDL considers several critical conditions such as 7Q10 flows, high ambient and water temperatures, high salinity in segments up to the confluence with the Delaware river, and MOT discharges at maximum permitted levels. Since the possibility of occurrence of all these critical conditions at the same time is rare, the above consideration contributes to the implicit margin of safety. Therefore, it can be concluded that an implicit margin of safety has been considered for this TMDL analysis.

### *7.0 The proposed Appoquinimink River Watershed TMDL has been subject to public participation.*

The EPA held a public hearing prior to the adoption of the 1998 TMDL covering the mainstem of the Appoquinimink river. During the adoption period of the '98 TMDL, DNREC and the public had an opportunity to present comments.

Another important public participation activity regarding this TMDL was the formation of the Appoquinimink Tributary Action Team last year. The Tributary Action Team, made up of concerned citizens and other affected parties within the watershed, has met several times and will assist the DNREC in developing pollution control strategies (PCS) to implement the requirements of the proposed Appoquinimink River Watershed TMDL.

In addition to the public participation and stakeholder involvement mentioned above, a public workshop and public hearing has been scheduled for December 5, 2001 to present the proposed Appoquinimink River Watershed TMDL to the general public and receive comments prior to formal adoption of the TMDL regulation.

### *8.0 There should be a reasonable assurance that the proposed Appoquinimink River Watershed TMDL can be met.*

The proposed Appoquinimink River Watershed TMDL considers the reduction of nutrients and oxygen consuming pollutants (CBOD) from point and nonpoint sources. The magnitude of load reductions suggested by the proposed TMDL is in line with the current TMDL and is technically feasible and financially affordable. Following the adoption of the TMDL, the Appoquinimink River Tributary Action Team will assist the Department in developing a PCS to implement the requirements of the Appoquinimink River Watershed TMDL Regulation. The DNREC is planning to finalize and adopt the Appoquinimink River PCS within one year after formal adoption of the TMDL Regulation.

# 7. REFERENCES

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## Appendix C: WASP Model Calibration and Validation Results

The objective of this Appendix is to present calibration and validation results for the WASP model of the Appoquinimink River. Calibration results (May through July, 1991) are presented on pages C-2 through C-5 and validation results (August through October, 1991) are presented on pages C-6 through C-9. The tables at the end of this section present the mean, minimum, and maximum 1991 water quality monitoring sample values (in that order) used in the calibration and validation (source: DNREC).

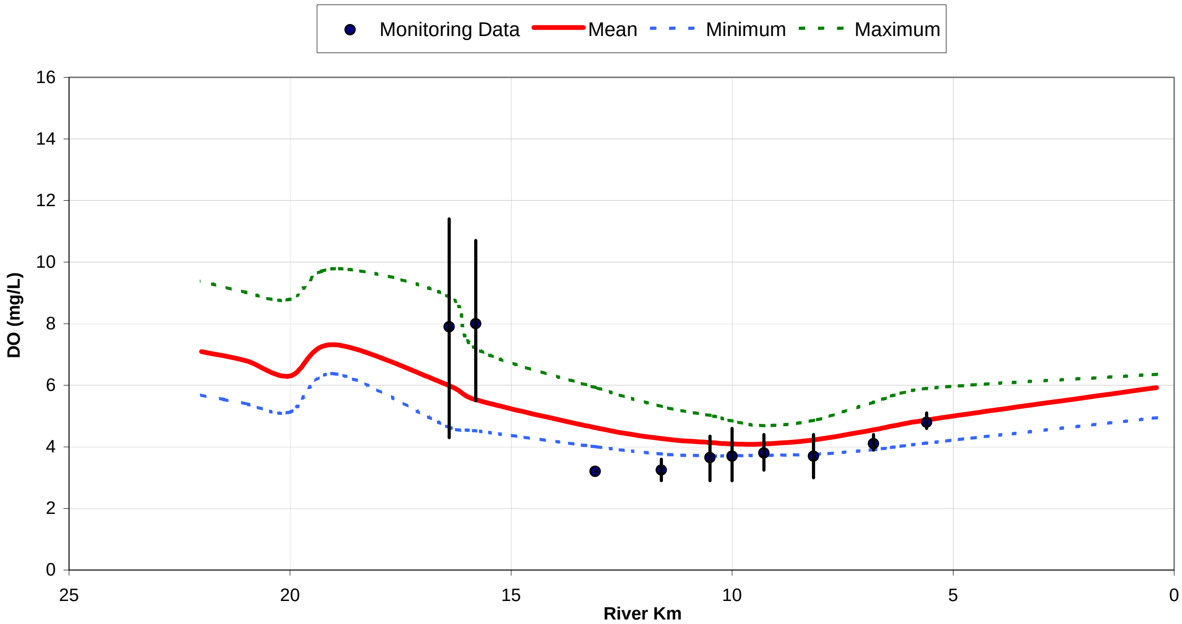



**Figure C-1.** Dissolved Oxygen Calibration for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for May through July, 1991

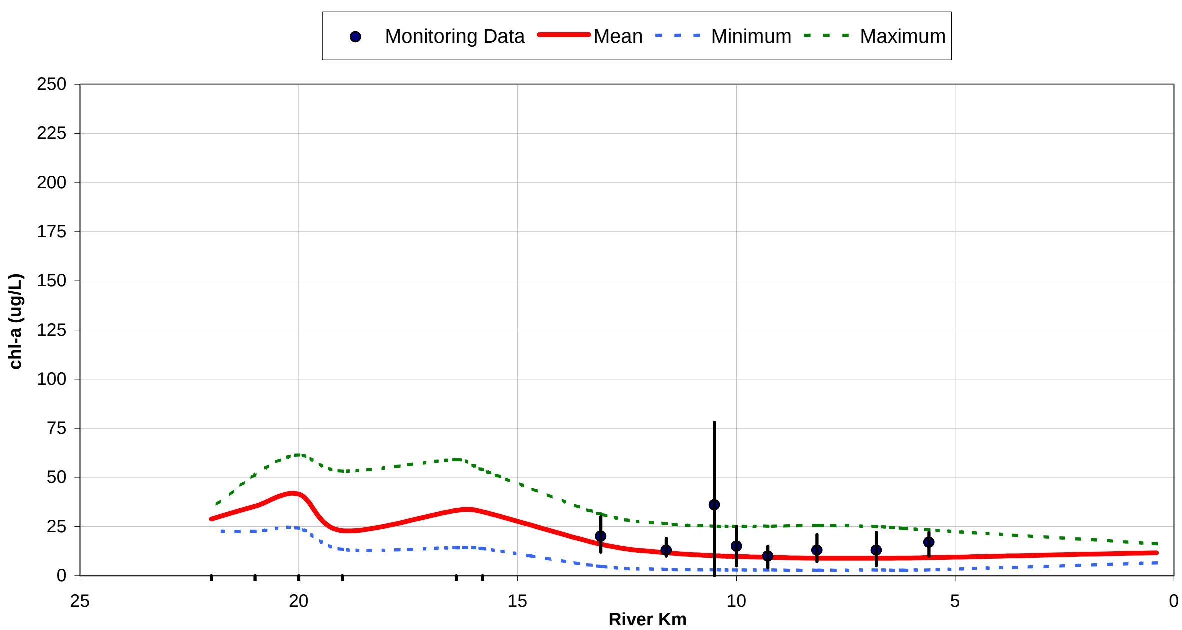



**Figure C-2**. Chlorophyll-a Calibration for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for May through July, 1991

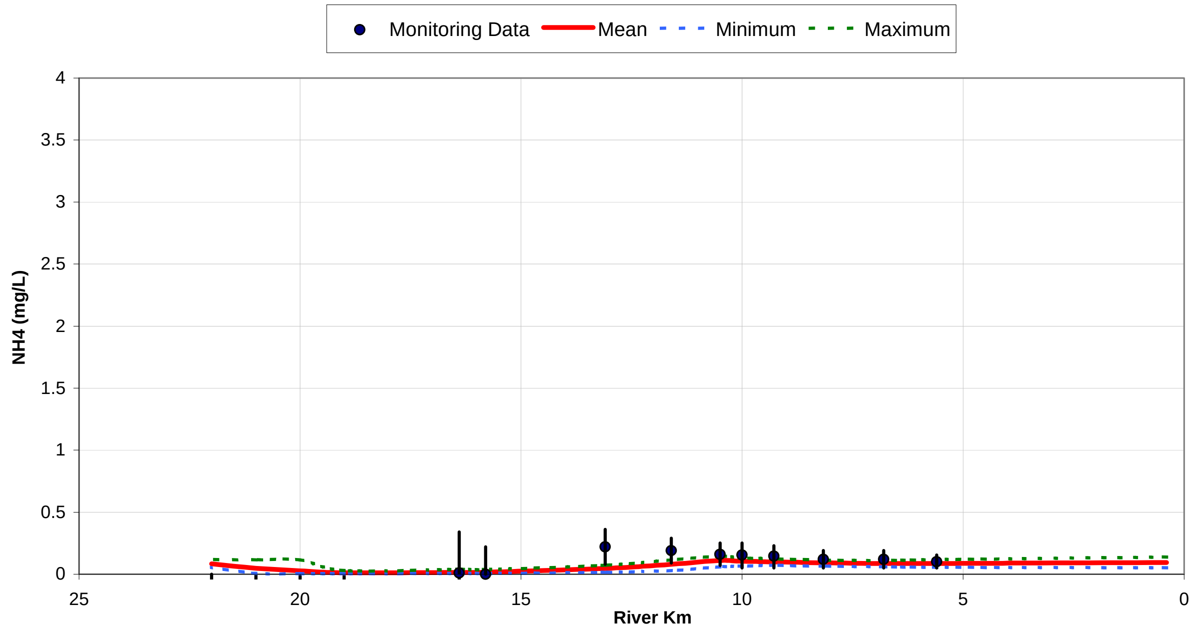



**Figure C-3.** NH4 Calibration for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for May through July, 1991

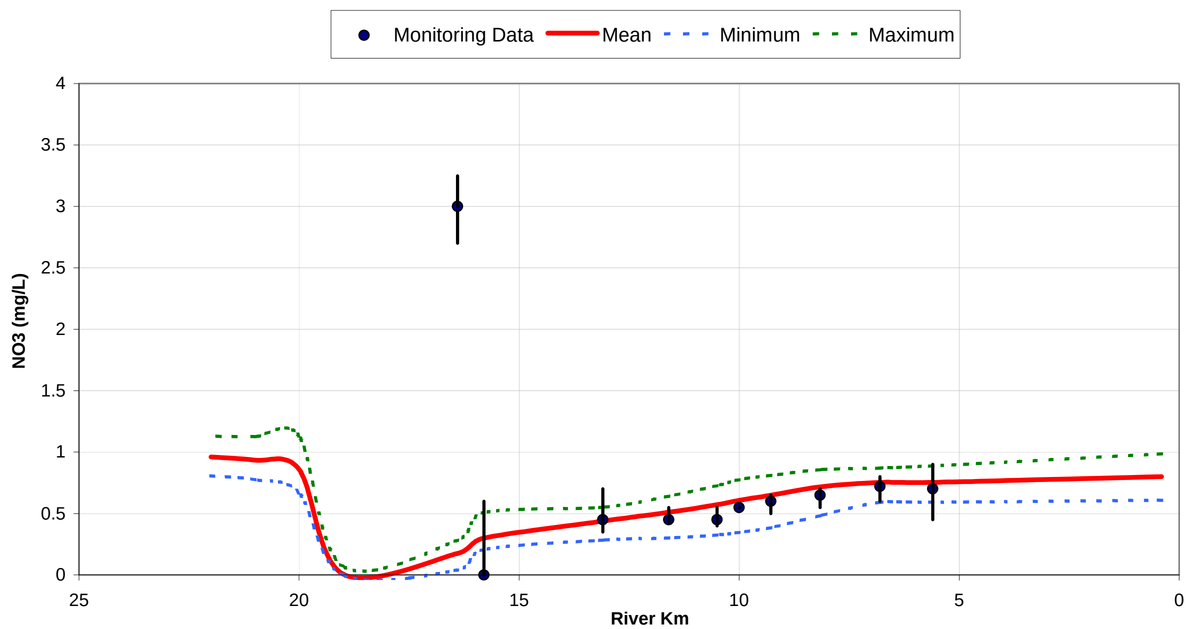



**Figure C-4.** NO3 Calibration for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for May through July, 1991

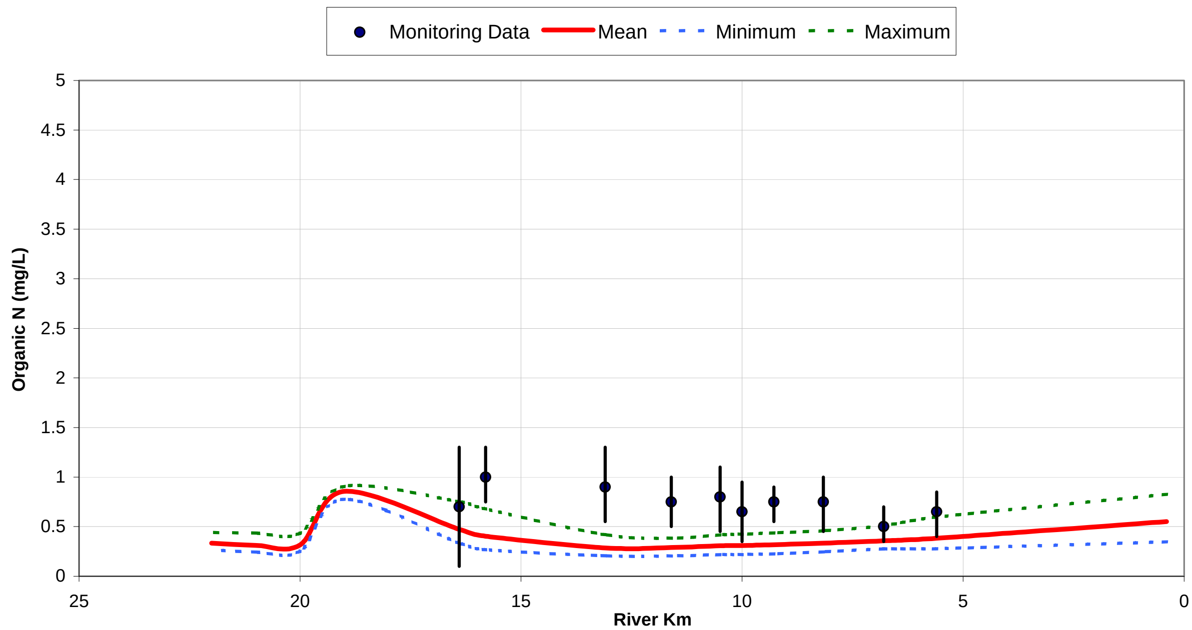



**Figure C-5.** Organic-N Calibration for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for May through July, 1991

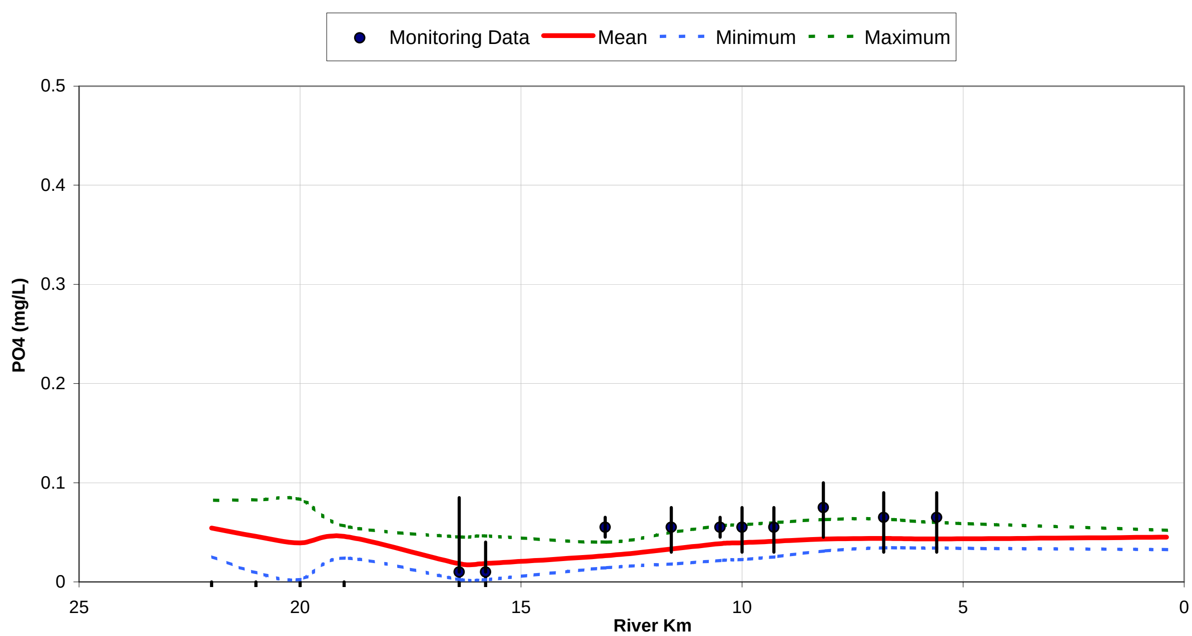



**Figure C-6.** PO4 Calibration for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for May through July, 1991

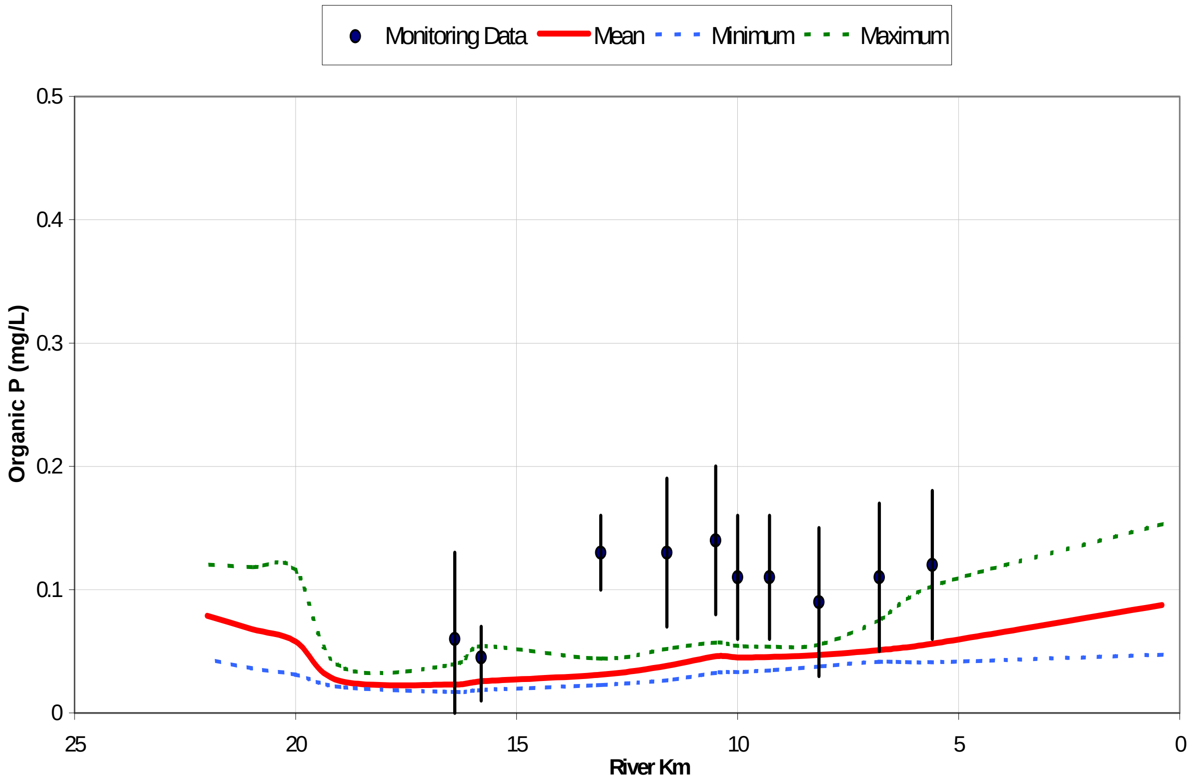



**Figure C-7.** Organic-P Calibration for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for May through July, 1991

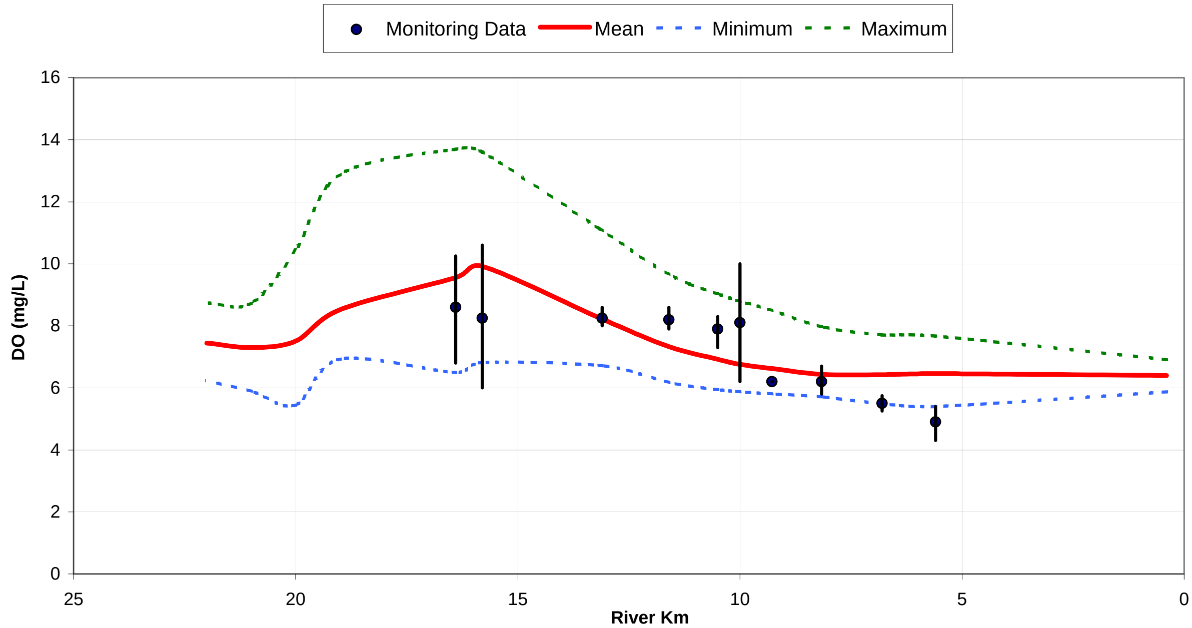



**Figure C-8.** Dissolved Oxygen Validation for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for August through October, 1991

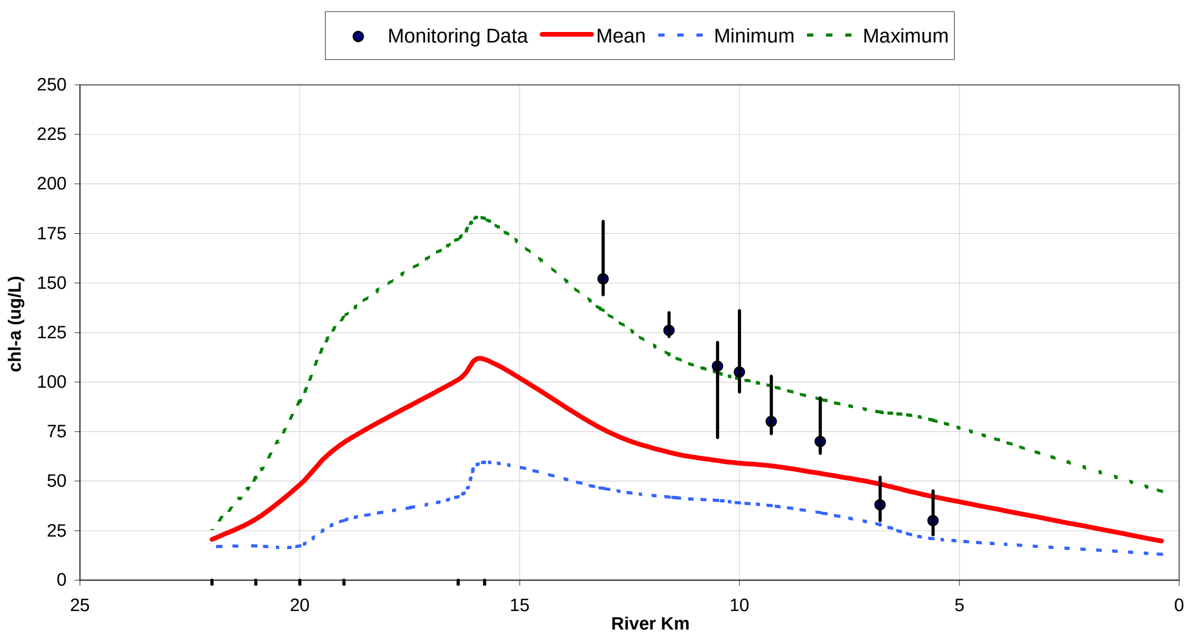



**Figure C-9.** Chlorophyll-a Validation for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for August through October, 1991

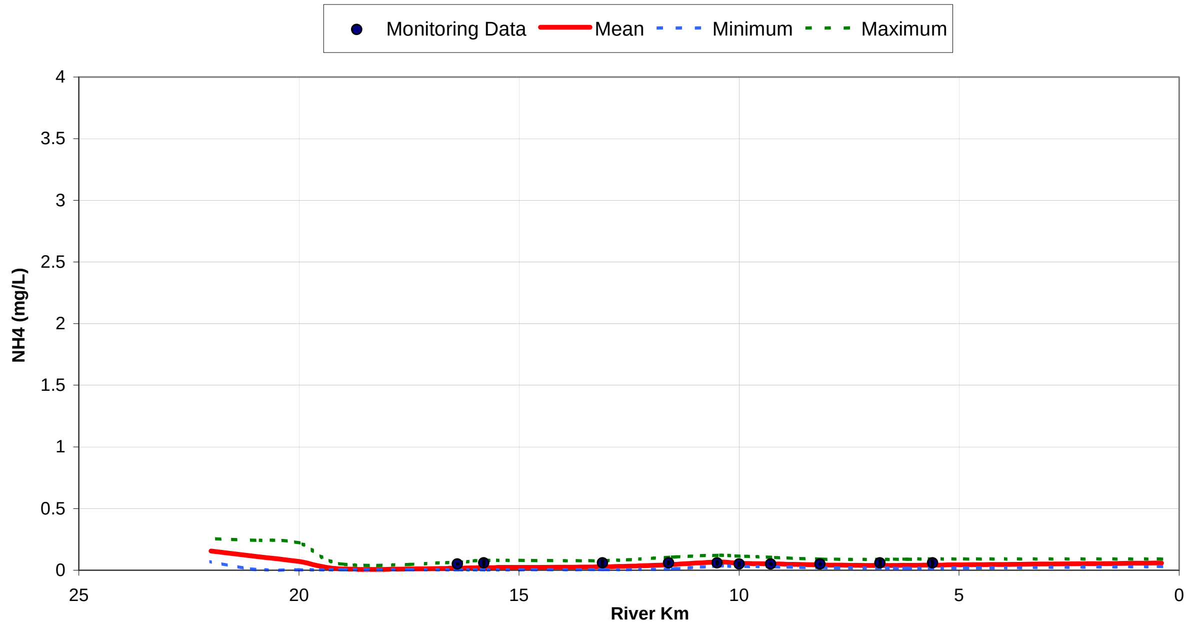



**Figure C-10.** NH4 Validation for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for August through October, 1991

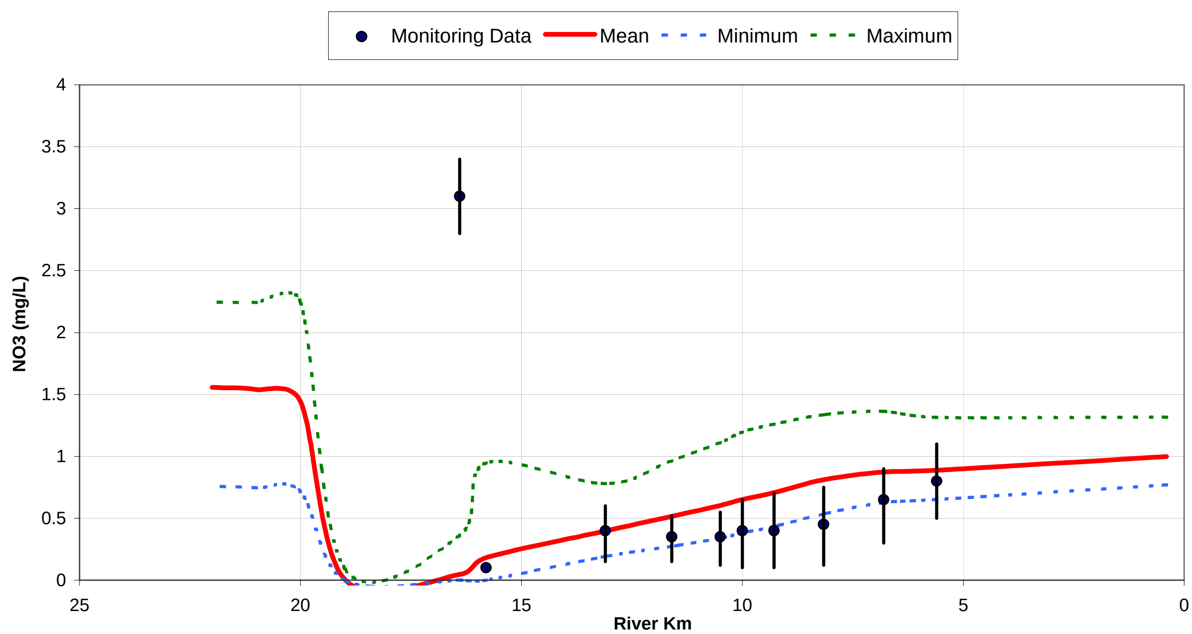



**Figure C-11.** NO3 Validation for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for August through October, 1991

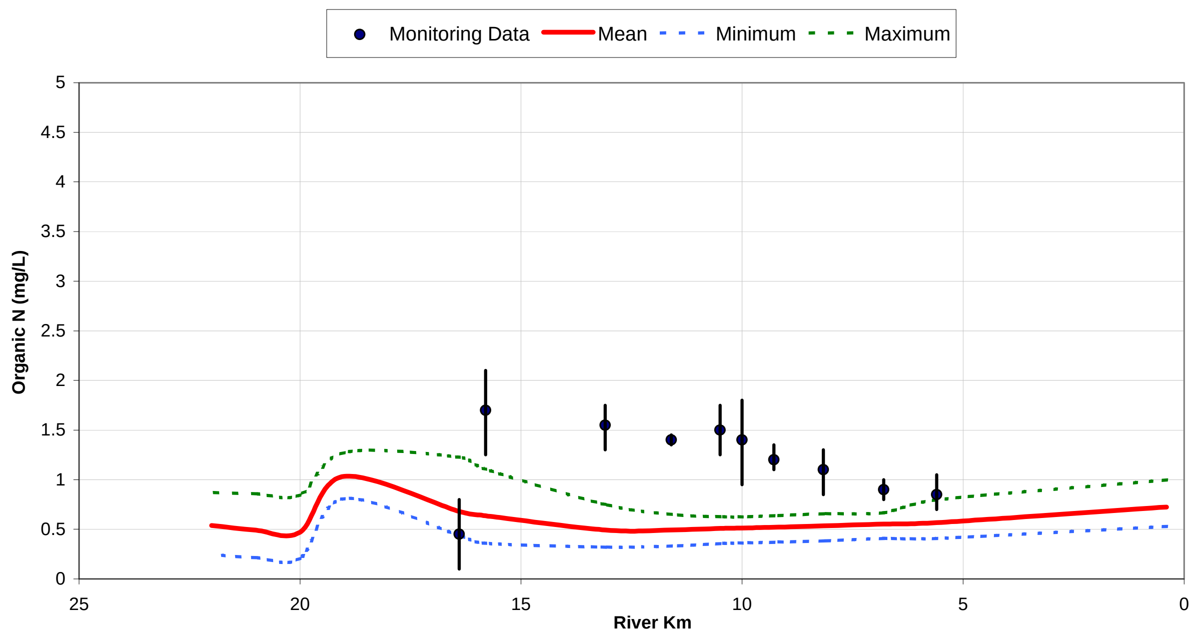



**Figure C-12.** Organic-N Validation for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for August through October, 1991

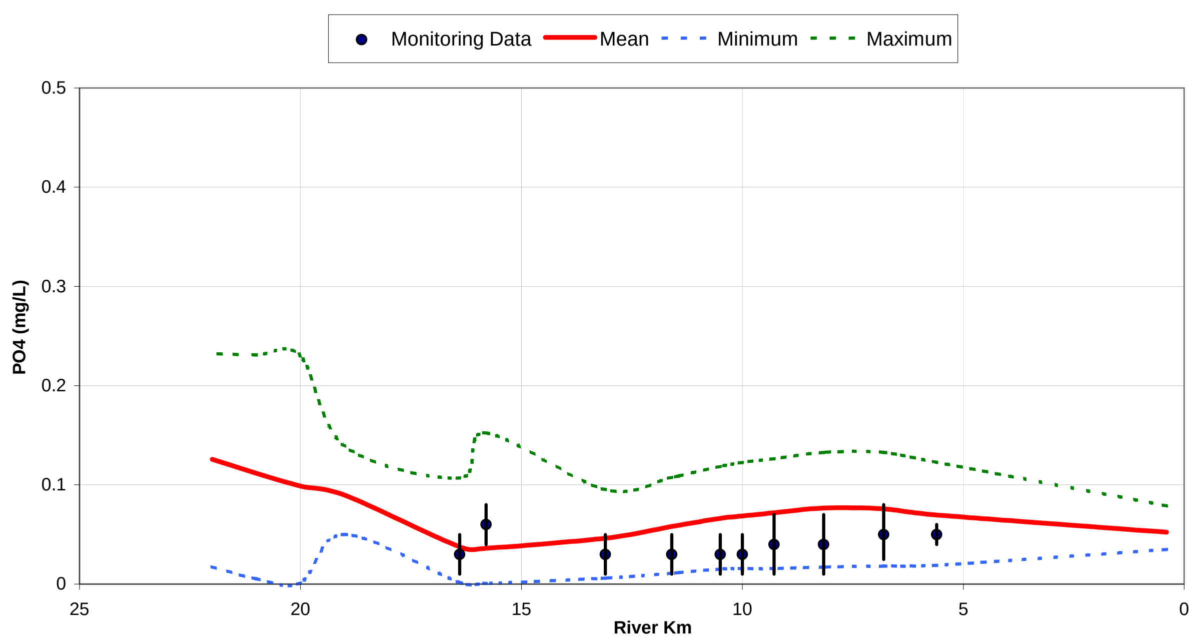



**Figure C-13.** PO4 Validation for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for August through October, 1991

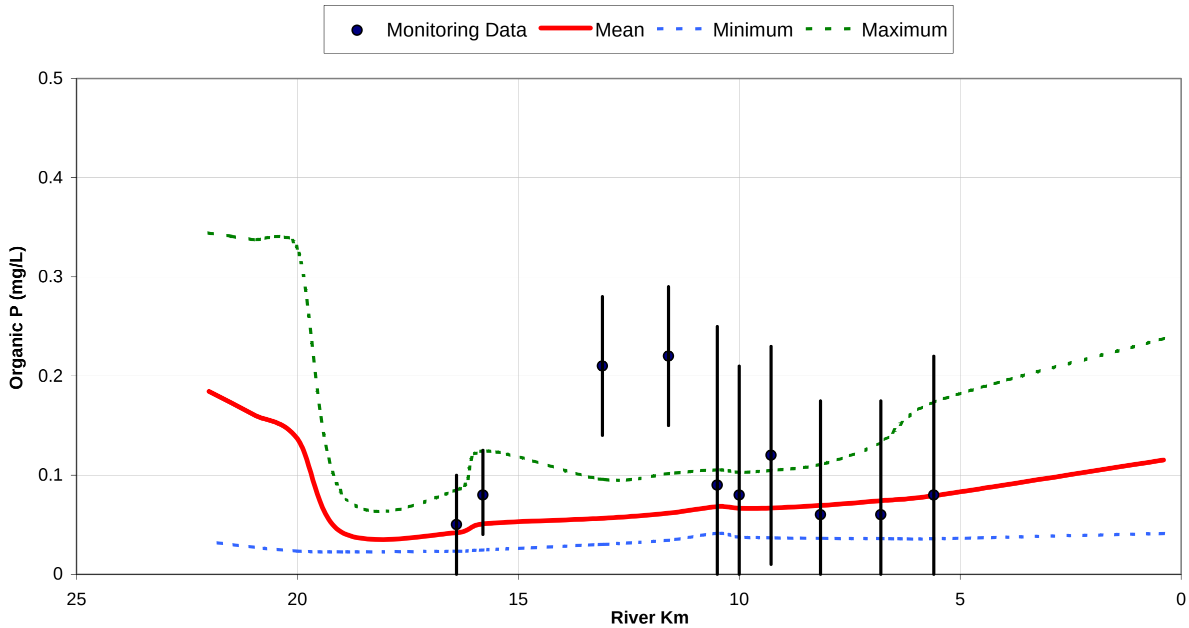



**Figure C-14.** Organic-P Validation for the Appoquinimink River: Minimum, Maximum, and Mean Concentrations for August through October, 1991

**Table C-1.** Dissolved Oxygen and Chlorophyll-a Data for the Appoquinimink River: May through July and August through October, 1991

| | | DO (mg/L) | | | Chlorophyll a (ug/L) | | |
|---|---|---|---|---|---|---|---|
| Time Period | Distance from Downstream (km) | mean | min | max | mean | min | max |
| Aug-Oct | 0.40 | -9.00 | -9.00 | -9.00 | -9.00 | -9.00 | -9.00 |
| Aug-Oct | 5.60 | 4.90 | 4.30 | 5.40 | 30.00 | 12.00 | 45.00 |
| Aug-Oct | 6.80 | 5.50 | 5.25 | 5.75 | 38.00 | 28.00 | 52.00 |
| Aug-Oct | 8.16 | 6.20 | 5.80 | 6.70 | 70.00 | 47.00 | 92.00 |
| Aug-Oct | 9.28 | 6.20 | 6.20 | 6.20 | 80.00 | 65.00 | 103.00 |
| Aug-Oct | 10.00 | 8.10 | 6.20 | 10.00 | 105.00 | 72.00 | 136.00 |
| Aug-Oct | 10.56 | 7.90 | 7.30 | 8.30 | 108.00 | 95.00 | 120.00 |
| Aug-Oct | 11.60 | 8.20 | 7.90 | 8.60 | 126.00 | 118.00 | 135.00 |
| Aug-Oct | 13.12 | 8.25 | 8.00 | 8.60 | 152.00 | 124.00 | 181.00 |
| Aug-Oct | 15.84 | 8.25 | 6.00 | 10.60 | -9.00 | -9.00 | -9.00 |
| Aug-Oct | 16.40 | 8.60 | 6.80 | 10.25 | -9.00 | -9.00 | -9.00 |
| May-July | 0.40 | -9.00 | -9.00 | -9.00 | -9.00 | -9.00 | -9.00 |
| May-July | 5.60 | 4.80 | 4.60 | 5.10 | 17.00 | 10.00 | 22.00 |
| May-July | 6.80 | 4.10 | 3.90 | 4.40 | 13.00 | 5.00 | 22.00 |
| May-July | 8.16 | 3.70 | 3.00 | 4.40 | 13.00 | 7.00 | 21.00 |
| May-July | 9.28 | 3.80 | 3.25 | 4.40 | 10.00 | 4.00 | 15.00 |
| May-July | 10.00 | 3.70 | 2.90 | 4.60 | 15.00 | 5.00 | 25.00 |
| May-July | 10.56 | 3.65 | 2.90 | 4.35 | 36.00 | 0.00 | 78.00 |
| May-July | 11.60 | 3.25 | 2.90 | 3.60 | 13.00 | 10.00 | 19.00 |
| May-July | 13.12 | 3.20 | 3.20 | 3.20 | 20.00 | 12.00 | 30.00 |
| May-July | 15.84 | 8.00 | 5.50 | 10.70 | -9.00 | -9.00 | -9.00 |
| May-July | 16.40 | 7.90 | 4.30 | 11.40 | -9.00 | -9.00 | -9.00 |

**Table C-2.** NH3-N, NO2-NO3-N, and Organic-N Data for the Appoquinimink River: May through July and August through October, 1991

| | | NH3-N (mg/L) | | | NO2-NO3-N (mg/L) | | | Organic-N (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Time Period | Distance from Downstream (km) | mean | min | max | mean | min | max | mean | min | max |
| Aug-Oct | 0.40 | -9.000 | -9.000 | -9.000 | -9.00 | -9.00 | -9.00 | -9.000 | -9.000 | -9.000 |
| Aug-Oct | 5.60 | 0.060 | 0.040 | 0.080 | 0.80 | 0.50 | 1.10 | 0.850 | 0.700 | 1.050 |
| Aug-Oct | 6.80 | 0.060 | 0.040 | 0.080 | 0.65 | 0.30 | 0.90 | 0.900 | 0.800 | 1.000 |
| Aug-Oct | 8.16 | 0.050 | 0.050 | 0.050 | 0.45 | 0.12 | 0.75 | 1.100 | 0.850 | 1.300 |
| Aug-Oct | 9.28 | 0.050 | 0.050 | 0.050 | 0.40 | 0.10 | 0.70 | 1.200 | 1.100 | 1.350 |
| Aug-Oct | 10.00 | 0.050 | 0.040 | 0.060 | 0.40 | 0.10 | 0.65 | 1.400 | 0.950 | 1.800 |
| Aug-Oct | 10.56 | 0.060 | 0.050 | 0.070 | 0.35 | 0.12 | 0.55 | 1.500 | 1.250 | 1.750 |
| Aug-Oct | 11.60 | 0.060 | 0.050 | 0.070 | 0.35 | 0.15 | 0.52 | 1.400 | 1.350 | 1.450 |
| Aug-Oct | 13.12 | 0.060 | 0.040 | 0.080 | 0.40 | 0.15 | 0.60 | 1.550 | 1.300 | 1.750 |
| Aug-Oct | 15.84 | 0.060 | 0.040 | 0.080 | 0.10 | 0.10 | 0.10 | 1.700 | 1.250 | 2.100 |
| Aug-Oct | 16.40 | 0.050 | 0.050 | 0.050 | 3.10 | 2.80 | 3.40 | 0.450 | 0.100 | 0.800 |
| May-July | 0.40 | -9.00 | -9.00 | -9.00 | -9.00 | -9.00 | -9.00 | -9.00 | -9.00 | -9.00 |
| May-July | 5.60 | 0.100 | 0.050 | 0.155 | 0.70 | 0.45 | 0.90 | 0.650 | 0.400 | 0.850 |
| May-July | 6.80 | 0.120 | 0.050 | 0.190 | 0.72 | 0.60 | 0.80 | 0.500 | 0.350 | 0.700 |
| May-July | 8.16 | 0.120 | 0.050 | 0.190 | 0.65 | 0.55 | 0.70 | 0.750 | 0.450 | 1.000 |
| May-July | 9.28 | 0.145 | 0.050 | 0.230 | 0.60 | 0.50 | 0.65 | 0.750 | 0.550 | 0.900 |
| May-July | 10.00 | 0.155 | 0.050 | 0.250 | 0.55 | 0.55 | 0.55 | 0.650 | 0.350 | 0.950 |
| May-July | 10.56 | 0.160 | 0.070 | 0.250 | 0.45 | 0.40 | 0.55 | 0.800 | 0.450 | 1.100 |
| May-July | 11.60 | 0.190 | 0.090 | 0.290 | 0.45 | 0.42 | 0.55 | 0.750 | 0.500 | 1.000 |
| May-July | 13.12 | 0.220 | 0.080 | 0.360 | 0.45 | 0.35 | 0.70 | 0.900 | 0.550 | 1.300 |
| May-July | 15.84 | 0.110 | 0.000 | 0.220 | 0.45 | 0.00 | 1.05 | 1.000 | 0.750 | 1.300 |
| May-July | 16.40 | 0.170 | 0.010 | 0.330 | 3.30 | 3.00 | 3.55 | 0.700 | 0.100 | 1.300 |

**Table C-3.** PO4-P and Organic-P Data for the Appoquinimink River: May through July and August through October, 1991

| | | PO4-P (mg/L) | | | Organic-P (mg/L) | | |
|---|---|---|---|---|---|---|---|
| Time Period | Distance from Downstream (km) | mean | min | max | mean | min | max |
| Aug-Oct | 0.40 | -9.000 | -9.000 | -9.000 | -9.000 | -9.000 | -9.000 |
| Aug-Oct | 5.60 | 0.050 | 0.040 | 0.060 | 0.080 | 0.000 | 0.220 |
| Aug-Oct | 6.80 | 0.050 | 0.025 | 0.080 | 0.060 | 0.000 | 0.175 |
| Aug-Oct | 8.16 | 0.040 | 0.010 | 0.070 | 0.060 | 0.000 | 0.175 |
| Aug-Oct | 9.28 | 0.040 | 0.010 | 0.070 | 0.120 | 0.010 | 0.230 |
| Aug-Oct | 10.00 | 0.030 | 0.010 | 0.050 | 0.080 | 0.000 | 0.210 |
| Aug-Oct | 10.56 | 0.030 | 0.010 | 0.050 | 0.090 | 0.000 | 0.250 |
| Aug-Oct | 11.60 | 0.030 | 0.010 | 0.050 | 0.220 | 0.150 | 0.290 |
| Aug-Oct | 13.12 | 0.030 | 0.010 | 0.050 | 0.210 | 0.140 | 0.280 |
| Aug-Oct | 15.84 | 0.060 | 0.040 | 0.080 | 0.080 | 0.040 | 0.125 |
| Aug-Oct | 16.40 | 0.030 | 0.010 | 0.050 | 0.050 | 0.000 | 0.100 |
| May-July | 0.40 | -9.00 | -9.00 | -9.00 | -9.00 | -9.00 | -9.00 |
| May-July | 5.60 | 0.065 | 0.030 | 0.090 | 0.120 | 0.060 | 0.180 |
| May-July | 6.80 | 0.065 | 0.030 | 0.090 | 0.110 | 0.050 | 0.170 |
| May-July | 8.16 | 0.075 | 0.045 | 0.100 | 0.090 | 0.030 | 0.150 |
| May-July | 9.28 | 0.055 | 0.030 | 0.075 | 0.110 | 0.060 | 0.160 |
| May-July | 10.00 | 0.055 | 0.030 | 0.075 | 0.110 | 0.060 | 0.160 |
| May-July | 10.56 | 0.055 | 0.045 | 0.065 | 0.140 | 0.080 | 0.200 |
| May-July | 11.60 | 0.055 | 0.030 | 0.075 | 0.130 | 0.070 | 0.190 |
| May-July | 13.12 | 0.055 | 0.045 | 0.065 | 0.130 | 0.100 | 0.160 |
| May-July | 15.84 | 0.025 | 0.010 | 0.030 | 0.045 | 0.010 | 0.070 |
| May-July | 16.40 | 0.045 | 0.010 | 0.075 | 0.060 | 0.000 | 0.130 |

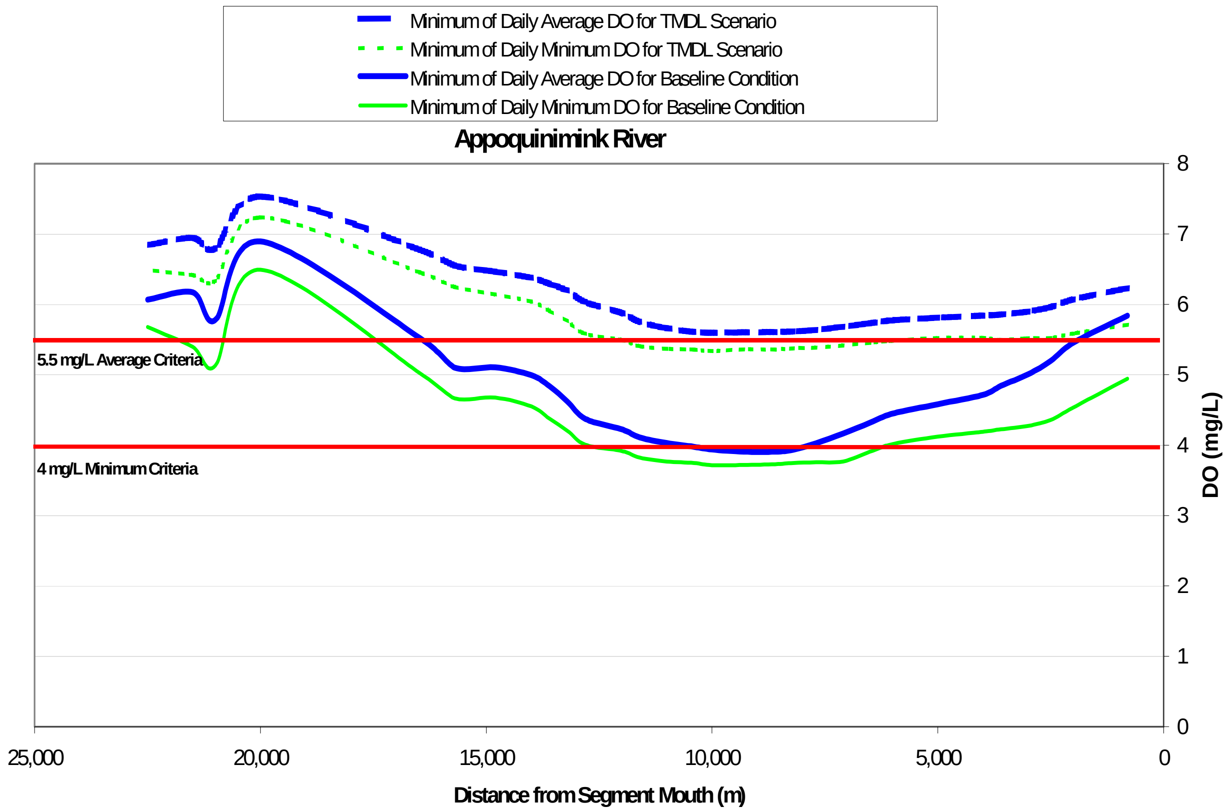
**Table C-4 .** Structural BMP Expected Pollutant Removal Efficiency

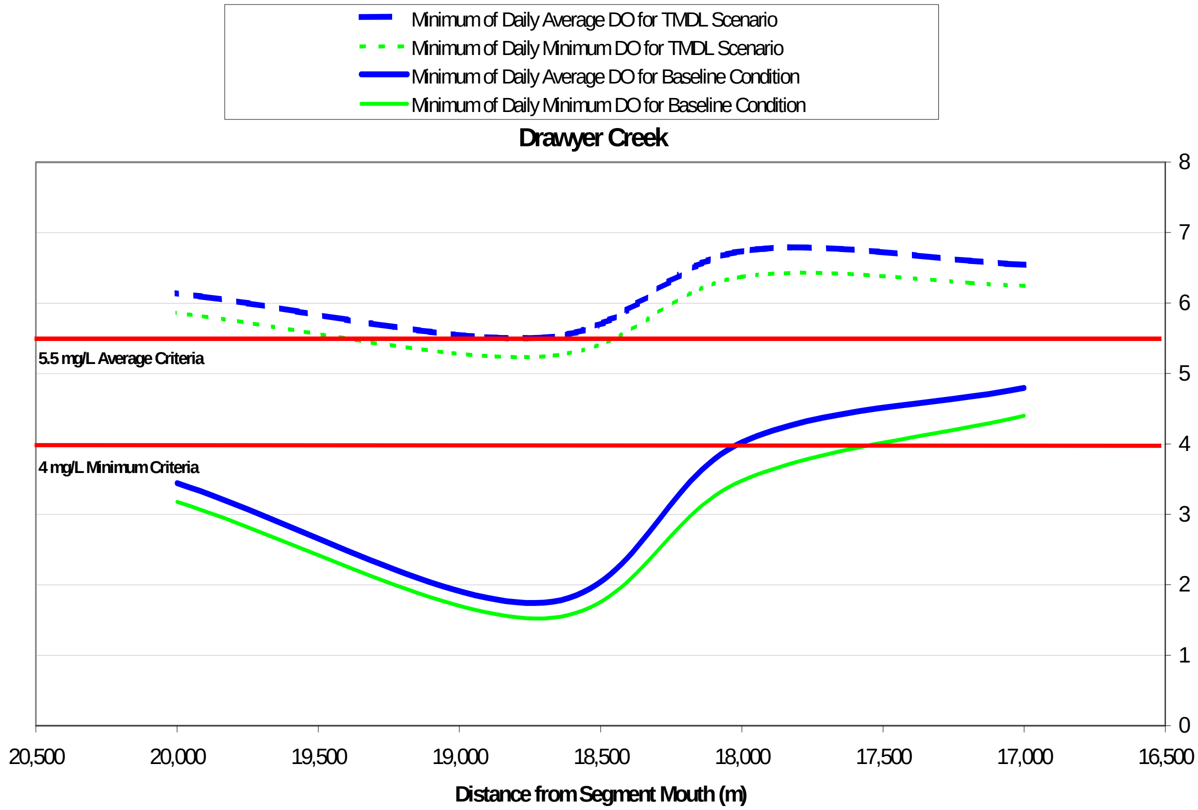
| BMP Type | Typical Pollutant Removal (percent)* | | |
|---|---|---|---|
| | Suspended Solids | Nitrogen | Phosphorous |
| Dry Detention Basin | 30 - 65 | 15 - 45 | 15 - 45 |
| Retention Basin | 50 - 80 | 30 - 65 | 30 - 65 |
| Constructed Wetlands | 50 - 80 | <30 | 15 - 45 |
| Infiltration Basins | 50 - 80 | 50 -80 | 50 -80 |
| Infiltration Trenches/ Dry Wells | 50 - 80 | 50 - 80 | 15 - 45 |
| Porous Pavement | 65 - 100 | 65 - 100 | 30 - 65 |
| Grassed Swales | 30 - 65 | 15 - 45 | 15 - 45 |
| Vegetated Filter Strips | 50 - 80 | 50 - 80 | 50 - 80 |
| Surface Sand Filters | 50 - 80 | <30 | 50 - 80 |
| Other Media Filters | 65 - 100 | 15 - 45 | <30 |

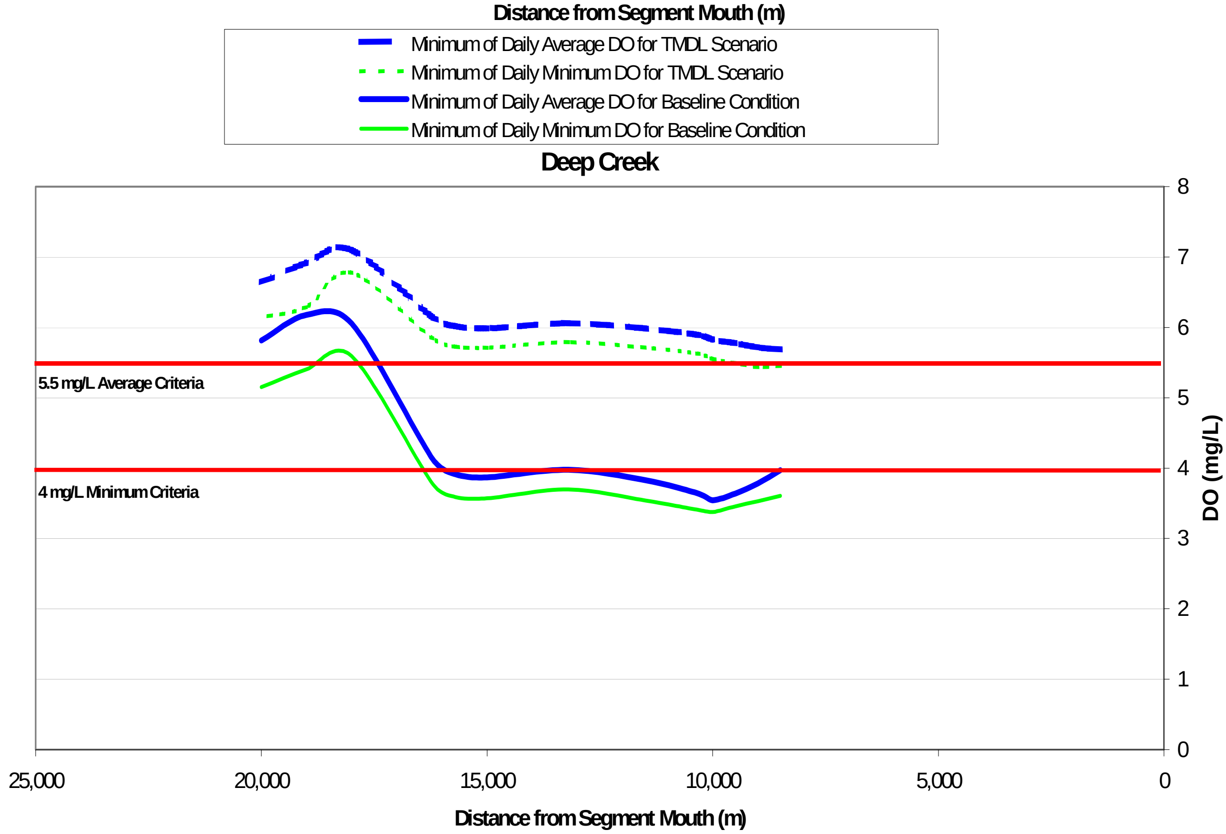
* Source, EPA, 1999. "Preliminary Data Summary of Urban Storm Water Best Management Practices" EPA # 821-R-99-012. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

# Appendix D: Dissolved Oxygen Modeling Results for Baseline and TMDL Scenarios

This Appendix presents modeling results for the baseline condition and a successful compliance scenario. The compliance scenario was used to identify TMDLs for the impaired waters in the Appoquinimink watershed. Plots on pages D-2 present modeling results for the Appoquinimink River and Deep Creek , respectively. The plot on page D-3 presents results for Drawyer Creek. The distances presented on the plot represent distances from the mouth of that particular segment.


Minimum of Daily Average DO for TMDL Scenario
Minimum of Daily Minimum DO for TMDL Scenario
Minimum of Daily Average DO for Baseline Condition
Minimum of Daily Minimum DO for Baseline Condition
Appoquinimink River
5.5 mg/L Average Criteria
4 mg/L Minimum Criteria
DO (mg/L)
8
7
6
5
4
3
2
1
0
25,000
20,000
15,000
10,000
5,000
0
Distance from Segment Mouth (m)


Minimum of Daily Average DO for TMDL Scenario
Minimum of Daily Minimum DO for TMDL Scenario
Minimum of Daily Average DO for Baseline Condition
Minimum of Daily Minimum DO for Baseline Condition
Drawyer Creek
5.5 mg/L Average Criteria
4 mg/L Minimum Criteria
DO (mg/L)
0
1
2
3
4
5
6
7
8
20,500
20,000
19,500
19,000
18,500
18,000
17,500
17,000
16,500
Distance from Segment Mouth (m)


Minimum of Daily Average DO for TMDL Scenario
Minimum of Daily Minimum DO for TMDL Scenario
Minimum of Daily Average DO for Baseline Condition
Minimum of Daily Minimum DO for Baseline Condition
Deep Creek
5.5 mg/L Average Criteria
4 mg/L Minimum Criteria
DO (mg/L)
0
1
2
3
4
5
6
7
8
25,000
20,000
15,000
10,000
5,000
0
Distance from Segment Mouth (m)

# Appoquinimink TMDL Responsiveness Summary
# Dec. 15, 2003

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Surles, Tracy | 01-01 | New Castle County was not provided with access to the model development process and was not provided with enough access to the model. | New Castle County was provided with the model on October 14, 2003, four days after the opening of the public comment period. Since the comment period was extended by one week, New Castle County had over 30 days to review the model. EPA provided assistance to New Castle County's contractor in operating the model. |
| Surles, Tracy | 01-02 | We see no reason why EPA did not have the TMDL and all supporting information ready for review by the public at the start of the 30-day comment period. | The TMDL was posted on the web at the start of the comment period. The model and Appendix B (DNREC's 2001 report) were not available on the web but were available upon request. The model was e-mailed to New Castle County on October 14, 2003. Since the comment period was extended by one week, New Castle County had over 30 days to review the model. Appendix B contained DNREC's 2001 report (the commentor mentioned they had commented upon this document) would have been furnished to the County upon request, however EPA was never contacted by the County in regards to the appendix even though it was contacted several times about the model. |
| Surles, Tracy | 01-03 | EPA has failed to provide important information for the public comment. EPA's approach left the public with little meaningful opportunity to comment on the accuracy of all of the modeling information. | EPA provided the public with over thirty days to review the TMDL and was available for contact after the release of the TMDL. New Castle County requested assistance from EPA on running the model. EPA provided this assistance quickly and in a professional manner. |
| Surles, Tracy | 01-04 | The Appoquinimink system is extensively influenced by marshes. EPA and DNREC should be aware of the several studies about the system and the previous technical information that was provided to DNREC during the public comment opportunity. | EPA is aware of the marsh systems associated with the Appoquinimink River. EPA believes that it was able to accurately characterize the stream system through the use of the models in the TMDL as evidenced in the calibration and validation process. Even though the model did not explicitly account for the marshes it still reflected the stream's conditions. |

# Appoquinimink TMDL Responsiveness Summary
# Dec. 15, 2003

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Surles, Tracy | 01-05 | The TMDL fails to address the marshes either from a hydraulic or water quality perspective. The model cannot yield dependable results without addressing the marshes. | Water quality monitoring data focused on evaluating the specific impacts of the tidal marshes were not available to support this study. As such, detailed processes associated with the marshes were not explicitly represented in the receiving water modeling framework (DYNHYD and WASP). Landuse data were available for the watershed, and thus the wetland areas (marshes) were represented as a distinct landuse category in the GWLF modeling framework. Because insufficient monitoring data were available to fully define the impact (in terms of a net gain or loss) of the wetlands, neither the detainment capacity nor loading processes were explicitly considered. The comment assumes the TMDL fails to account for the contribution of nutrients to the watershed from adjacent marshes. It is well-documented, however, that wetlands perform a nutrient uptake function by detaining land-based loads prior to their reaching the river. In this case, there is no data specific to marshes in the Appoquinimink River watershed, either as to the contribution or nutrients from those marshes or as the impact of the nutrient uptake functions performed by those marshes. Accordingly, while the GWLF model included wetlands as a distinct land use category, specific data as to detention in the marshes of land-based constituent loads from the watershed, which in a good portion of the Appoquinimink River watershed pass through wetlands prior to feeding into the rivers (and tributaries), were not considered. At the same time, contributions of nutrients and organic matter from the wetlands themselves were also not explicitly represented. Because the model was successfully calibrated through a comparison of predictions with in-stream monitoring data and did not indicate a major contributing source was being overlooked, it is reasonable to assume that contributions from the marshes was balanced by the nutrient uptake function in terms of loading to the river. |
| Surles, Tracy | 01-06 | The net effect of forcing the model to fit observed data, while ignoring the marshes, results in incorrectly attributing the impacts of the marshes to other sources | Please see response 01-05. |

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Surles, Tracy | 01-07 | The sensitivity analysis clearly demonstrates that the system is sensitive to SOD. The model treats SOD as a constant sink of D.O. associated with the bottom area of the stream. Because the impact of the marshes can be, at least partially conceptualized as a periodic expansion of the inundated area that exerts SOD, this should have been a signal that the marshes could not be neglected. | Water quality monitoring data focused on evaluating the specific impacts of the tidal marshes (including the ability to lower DO in the river) were not available to support this study. The SOD was predicted using a sediment diagenesis model, and thus cannot physically be "inflated." The SOD was predicted based on a combination of factors, including loadings from the entire watershed and MOT and hydrologic regime. |
| Surles, Tracy | 01-08 | Because the DO standard for the river is not met due to the natural conditions, EPA should have done a use attainability analysis to identify the attainable D.O. level before doing a TMDL to achieve the standard. | To the extent the commenter argues that the TMDL is flawed because the applicable water quality standard is inherently deficient and could not be satisfied under any circumstance, the commenter's concerns are properly addressed to DNREC and not to this TMDL. TMDLs must, by law, be calculated to implement state water quality standards. This TMDL is an inappropriate forum for seeking a change in the state's water quality standards or the initiation of a use attainability analysis. Section 303(d)(1)(A) requires the State to identify waters for which technology-based limits are insufficient "to implement any water quality standard applicable to such waters." Section 303(d) is not an appropriate vehicle for disputing the appropriateness of specific State water quality standards. The appropriate vehicle for rectifying concerns regarding the appropriateness of a State water quality standard is EPA's authorities under Section 303(c). Under Delaware law implementing Section 303(c), water quality standards must be adopted as regulations through the state's normal notice-and-comment procedure. See Delaware WQS § §5.1, 5.2 (B-36-37). Any changes to a water quality standard must therefore also be adopted by the state through formal regulatory channels; in addition, any such changes must be approved by EPA. Id. Unless and until the the applicable water quality standard is changed pursuant to Section 303(c), it remains the only legally valid standard in place and the one that must be satisfied under Section 303(d). Nothing in the TMDL prevents DNREC from initiating a use attainability analysis. |

# Appoquinimink TMDL Responsiveness Summary
# Dec. 15, 2003

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Surles, Tracy | 01-09 | Why did EPA choose to ignore the attainability question given EPA's 1994 case study on the Appoquinimink River? | The conclusions of the 1994 study call on the following; to define the load reductions necessary to meet the DO criteria; further characterize nonpoint source nutrient loads; monitor and model the SOD; and specify how the TMDL will be implemented. The new TMDL is based on a new model which accounts for SOD and nonpoint sources of nutrients. The model also identifies the nutrient reductions that are necessary to attain the criteria. |
| Surles, Tracy | 01-10 | The applicable DO standard depends on whether the river is considered fresh or marine. EPA should recommend to DNREC that it specify the application of the marine standard. | EPA chose to develop the TMDL using the freshwater criteria. This is consistent with previous TMDL decisions by the state and EPA and is supported by the water quality data. As stated in the Technical Analysis for the Proposed Appoquinimink River TMDLs - October 2001, "the average salinity in the section of the Appoquinimink River between the confluence with the Delaware River and the intersection with Drawer Creek is above the saltwater salinity value of 5 ppt, but because the minimum is below the 5 ppt level, it is considered fresh water." EPA used Delaware's interpretation of their criteria for the TMDL endpoint. |
| Surles, Tracy | 01-11 | DNREC's data from 1997-2000 shows an average summer salinity: indicative of marine conditions as far as 5 km upstream from the Delaware River. For these areas, the draft TMDLs are more stringent than necessary and likely unattainable. | The summer salinity data reviewed by EPA showed that the salinity concentrations associated with fresh water criteria were more appropriate for the Appoquinimink River. Please see comment 1-10 for additional information. |
| Surles, Tracy | 01-12 | The TMDLs are being designed to meet critical (7Q10) conditions, when by definition there is extremely low fresh water flow. Therefore, it would be appropriate for these TMDLs to be designed to meet the marine D.O. standard- which is more likely the correct and attainable standard than the more stringent fresh water standard, especially in the lower portion of the river. | The current Appoquinimk TMDL was not developed for the 7Q10 flow, but was developed using a dynamic model which takes into account various storm and flow data. Therefore, it is more appropriate to use the fresh water criteria since this represents the stream condition. |

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Surles, Tracy | 01-13 | The use of the 5.0 mg/L marine DO standard is further supported by the natural background conditions of the river. As explained in the County's March 13, 2002 letter to Hearing Officer Rod Thompson, historical data demonstrate that th 5.5 mg/L standard cannot be achieved under critical conditions because of naturally occurring and other background conditions that have not been factored into the model. The basic problem is that the BOD, nutrients and SOD produced by surrounding salt marshes significantly reduce DO to the point that the river cannot meet the 5.5 mg/L standard. The TMDLs do not reflect this. | The model shows that the reduction in loadings called for in the TMDL will allow the Appoquinimnk River to attain the DO criteria for fresh water systems. EPA applied the fresh water criteria which was used by the state and EPA in previous TMDLs and is an appropriate interpretation of the DO criteria. |
| Surles, Tracy | 01-14 | DNREC has not specified that the marine standards should apply in the lower portion of the river. We believe that good science supports such a conclusion. EPA should initiate a UAA to address this issue. | DNREC has interpreted Delaware's water quality standard as applying the freshwater criteria. As a general matter, EPA will defer to a State's interpretation of its own water quality standard regulations, so long as that interpretation falls within the range of reasonable interpretations. In this case, DNREC determined to apply the freshwater criteria. DNREC's interpretation falls within the range of reasonable interpretations and is accepted by EPA. To the extent the commenter argues that the TMDL is flawed because the applicable water quality standard is inherently deficient and could not be satisfied under any circumstance, see response to 01-08. (Data Supporting this Decision) |
| Surles, Tracy | 01-15 | The available STORET data supports this view. DO levels during the June- September time frame during 2000-2001 fell below the 5.5 mg/L standard a significant amount of the time. At station 109121 90% of the DO values were below 5.5 mg/L. Almost every station we looked at had a significant number of samples below the standard. These results are almost certainly attributable to the marsh impacts. | Marsh impacts maybe impacting the DO concentration in the Appoquinimink River as stated in these comments. However, the marsh impacts are not the only factor impacting the low DO values. The model demonstrates that by reducing the elevated nutrient load that is reaching the River the DO impairment can be removed. The DO impairment is being impacted by both flow and load issues. To the extent the commenter implies the River will not be able to maintain the applicable criteria because of marsh related issues without addressing the excess nutrient loading, the comment does not reflect all conditions to the stream. |
| Surles, Tracy | 01-16 | The TMDL should be developed for both the 5.5 mg/L and 5.0 mg/L potential water quality standards. | The regulations require the TMDL to be developed for the applicable criteria therefore, the TMDL was developed for the DO concentrations associated with the fresh water criteria, 5.5mg/L. |

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Surles, Tracy | 01-17 | The Clean Water Act does not authorize EPA to make allocation decisions which have land use implications but preserves the role of state and local authorities in these matters. | To the extent the commenter suggests that, through the TMDL, EPA is impinging on State and local government's sovereignty to make local land use decisions, the commenter is mistaken. The commenter mistakenly equates the water quality-based approach with a regulatory control function. TMDLs established pursuant to Section 303(d) of the Clean Water Act merely afford EPA and the States the authority to identify all sources of impairments of water quality standards (point source and nonpoint source). A variety of allocation scenarios may achieve the water quality standard for the Appoquinimink River. The TMDL provides a breakout of the total loads for to the point sources and nonpoint sources and represents one allocation scenario. DNREC retains significant discretion as to how to implement the TMDL. As implementation of the established TMDL proceeds, DNREC may find that the applicable water quality standard can be achieved through other combinations of point and nonpoint source allocations that are more feasible and/or cost effective. If that happens, DNREC is free to re-run the model to propose a revised TMDL with an alternative allocation scenario that will achieve water quality standards. These procedures should be followed even if the sum of the loads remains identical. By transferring the loadings from one source to another the results of the model may change. The proximity and timing of the different sources impacts the river differently. |
| Surles, Tracy | 01-18 | EPA should include a chart that shows the available loadings for the limited parameters as well as the percent allocation between point and nonpoint sources as well as any margin of safety and reserved growth loadings. | Table 4-1 presents the available loadings for nonpoint sources (in the WLA column) and Table 4-2 presents the available loadings for point sources. The Margin of Safety was implicit, and thus not explicitly quantified. Therefore, it was not presented in the tables. No assignment was made to reserved loadings for growth. |
| Surles, Tracy | 01-19 | EPA should expressly acknowledge in the TMDL that any other allocation scenario that meets the total loadings is allowable within DNREC's discretion. | See response to 01-17. |

# Appoquinimink TMDL Responsiveness Summary
# Dec. 15, 2003

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Surles, Tracy | 01-20 | The sensitivity analysis is grossly inadequate. It does not provide any meaningful insight into how the system reacts to alternate input scenarios. | Although the sensitivity of modeling parameters and source contributions were evaluated during the model calibration/validation and allocation efforts, respectively, a full sensitivity analysis (which is not a regulatory requirement) was not presented in the TMDL report. The model was made available to the public, so that the public would have the ability to make sensitivity runs as they see fit. |
| Surles, Tracy | 01-21 | We would like to have seen sensitivity runs using different pollutant concentrations from our MOT treatment plant. | While the commenter suggests that there should have been additional sensitivity runs, the commenter failed to propose any alternative allocation scenarios, other than the commenter's request in its letter dated September 2, 2003 (which was based on an August 2003 meeting between New Castle County and EPA) seeking an allocation scenario that would increase the effluent from the MOT plant by a factor of 5. At the commenter's request, EPA ran the model increasing the loading from the MOT plant by the values requested in the letter. The model predicted that these loadings (CBOD 104 lbs/day, TN 104 lbs/day, TP 83 lbs/day) from the MOT plant would cause a failure to achieve water quality standards, even if the storm water sources were reduced by the amount called for in the TMDL. Accordingly, a WLA was selected that did not require a reduction from the MOT plant. As stated in response to 01-17, the TMDL represents one allocation scenario, and DNREC remains free to re-run the model and propose a revised TMDL with a different allocation scenario. |
| Surles, Tracy | 01-22 | Why was an effluent DO value of 0.695 mg/L used for the MOT plant when it has not discharged at such a low level. A more appropriate level in the range of 5 to 7 mg/L should have been evaluated. | A DO value of 0.695 mg/L was used for the MOT discharge to be consistent with DNREC=s original DYNHYD-WASP model of the Appoquinimink River. This value was used as part of the 1998 TMDL, increasing the DO concentration in the effluent is not expected to impact the model results. |
| Surles, Tracy | 01-23 | EPA did not provide enough time for the public to access the model and run alternative allocations. | EPA did provide an adequate amount of time and assistance in the public comment period. Please see responses to comment 1. |
| Surles, Tracy | 01-24 | Why does the model not reflect seasonal nitrogen inputs to the Appoquinimink River from the emergent herbaceous wetlands which represent 9.82% of the land use in the watershed. | Emergent and Woody Wetlands were assumed to have no net load contribution due to their capacity to detain and/or utilize nutrient inputs (since these processes were not explicitly represented in the modeling framework). See response to 01-05. |

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Surles, Tracy | 01-25 | Routine, scientifically correct investigations, from 1995 to the present of the chemistries and fishes in the Appoquinimink by DNREC demonstrate that the aquatic life use is being protected throughout the Appoquinimink. This is despite the fact that DO's below the minimum criteria are routinely measured. | Section 303(d) requires that each state identify and develop TMDLs for those waters for which technology-based effluent limitations are not stringent enough to implement "any water quality standard applicable to such waters." Applicable water quality standards includes narrative criteria, numeric criteria, use designations and anti-degradation. All four parts of the water quality standard must be considered. In this case, although there may be studies showing that the Appoquinimink River supports aquatic life, the evidence also shows that the river fails to achieve the numeric criteria for DO. Waters which fail to attain their numeric criteria must be listed on the Section 303(d) List as impaired for TMDL development. The attainment of a healthy benthic community does not cancel out the violations to the DO criteria. |
| Surles, Tracy | 01-26 | Why is the wetlands tidally influenced reduction of DO concentrations not listed as a factor contributing to lower DO concentrations in the river? Why is an inflated SOD used to compensate for the lack of wetlands influenced reduction in DO? | Water quality monitoring data focused on evaluating the specific impacts of the tidal marshes (including the ability to lower DO in the river) were not available to support this study. The SOD was predicted using a sediment diagenesis model, and thus cannot physically be "inflated." The SOD was predicted based on a combination of factors, including loadings from the entire watershed and MOT and hydrologic regime. |

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Surles, Tracy | 01-27 | Please provide a numerical example of the conversion of monthly GWLF TN and TP outputs to daily values. Please explain how the model mathematically calculates the interaction between wetlands functions and rainfall related runoff events to the river's mainstem. | The conversion of monthly GWLF outputs to daily was performed as follows:<br><br>Assuming:<br>~ there are 30 days in a month<br>~ the monthly load of constituent X is 1,000 lb/month<br>~ monthly average flow is 3 cms<br>~ during the month there are only two rainfall events of 6 inches and 8 inches, respectively, on day 7 and day 11. Therefore, the total rainfall during the month is 14 inches.<br><br>For those days without rainfall, a baseflow was first assumed (0.1 cms), thus the total flow for the 28 days without rainfall was 0.1 x 28 = 2.8 cms (cms is used instead of cubic meters for simplicity). The total flows for the other two days was thus (3 x 30) - 2.8 = 87.2 cms.<br><br>Assuming the flow is directly proportional to rainfall, the flow on day 7 is:<br><br>(6 inch/14 inch) x 87.2 = 37.3 cms; and the flow on day 11 is:<br>(8 inch/14 inch) x 87.2 = 49.9 cms.<br><br>Due to the inherent uncertainty in these estimates, the fact that the resulting storm flows are attenuated with respect to the rainfall values, and the ultimate goal of predicting water quality trends over time in the river system due to storm flow and low flow conditions, these estimates were distributed over a multiple-day time period. This is a common practice in water quality modeling studies (such as in Deas and Orlob, 1999), where specific flow and water quality loads or concentrations for all individual storms are not monitored (and thus must be predicted). Based on the first estimate of the flow, the flow time series is distributed over time using a weighted moving average scheme, where the flow on day n is represented as:<br><br>Sum w(i)*Flow(n-K) from i--k to k.<br><br>Where: the weight vector w(i) is determined based on a triangular formula as w(-2)=0.1, w(-1)=0.2, w(0)=0.4, w(1)=0.2, and w(2)=0.1. As boundary condition, the Newflow(1) and Newflow(2) should be equal to the Flow(1) and Flow(2). |

| | | | |
|---|---|---|---|
| | | | By using this linear formula, the flow on day 3 is calculated as:<br><br>Newflow(7)=0.1*flow(5)+0.2*flow(6)+0.4*flow(7)+0.2*flow(8)+0.1*flow(9)=0.1*0.1+0.2*0.1+0.4*37.3+0.2*0.1+0.1*0.1=0.01+0.02+14.9+0.02+0.01=14.96 cms<br><br>Newflow(8)=0.1*flow(6)+0.2*flow(7)+0.4*flow(8)+0.2*flow(9)+0.1*flow(10)=0.01+7.46+0.04+0.02+0.01=7.54 cms<br><br>Using this formula, the distributed time series can be obtained for each day of the month. Then, the total load of 1,000 lbs is distributed to each day based on the assumption that the load of each day is proportional to the flow on that day.<br><br>There is no explicit hydrodynamic representation of the wetlands, however tidal influences are simulate. |
| Surles, Tracy | 01-28 | Will appendix B provided with the final document? | Appendix B was available during the comment period; it simply was not on the web site. Although it was not on the web site, New Castle County requested and received the model. Appendix B also could have been requested and would have been provided. New Castle County did not, however, request a copy of Appendix B during the comment period. The Appendix will be furnished to the commenter at this time. |
| Surles, Tracy | 01-29 | What is the source of SOD that is introducing nutrients to the water column? Would rainfall related runoff sediments be trapped in the surrounding wetlands?<br><br>Under the BNR conditions for the MOT previously provided to EPA would not MOT effluent be viewed as an insignificant source? | The source of the SOD is the organic matter loading from the watershed and the internal organic matter loading from algae death. Some of the watershed contributions are expected to be trapped in the surrounding wetlands, however, no information was available to accurately quantify the influence of the wetlands. Therefore, the wetlands were not explicitly represented in the modeling framework. The entire watershed load generated by the GWLF model was input directly into the DYNHYD- WASP model as a conservative assumption.<br><br>MOT effluent would not be viewed as an insignificant source under the BNR conditions provided since it is responsible for more than 1% of the nitrogen and phosphorous loadings. |

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Surles, Tracy | 01-30 | Why is the Gaussian temperature function considered to be more representative of real algal growth? We question whether the lack of algal growth in the summer is due to temperature and whether algae are limited by nutrients as claimed in the TMDL. | Algae, depending on species, typically grows the fastest when temperature is within the optimal range (given other condition are also optimal). When temperature is lower or higher than the optimal range, growth is generally reduced. This trend is well represented by the Gaussian function. Recent, advanced models use the Gaussian temperature function instead of the power function (Park et al, 1995; HydroQual, 2001). Algae growth is influenced by many factors, including temperature, nutrient levels, and light availability. Because no specific data were available regarding light availability, and because light availability was not expected to vary drastically between the calibration and validation periods, it was assumed that temperature and nutrient concentrations were the primary factors. Thus, the model reflected these influencing factors and successfully predicted chlorophyll a concentrations.<br><br>Nutrient loads throughout the year (including summer and fall) were predicted by the GWLF model. Thus, variability in nutrient levels (combined with flow) contributed by the watershed to the river was explicitly represented in the modeling framework. General observations regarding wetland functions are insufficient to explain cholorophyll-a concentrations in the Appoquinimink system under the calibration and validation conditions. The model predicts algae based on a host of factors specific to the Appoquinimink River system under specific conditions. |
| Surles, Tracy | 01-31 | Please explain why the use of a Kd decay rate value of 0.10/day resolves the previous model inconsistencies. What is the source and explanation for the selected Kd rate and why is it applicable to this river? | Previously, the Kd value was set as 0.075/day, while the CBODu/CBOD5 ratio was set as 1.58. A Kd value of 0.075/day, however, is associated with a CBODu/CBOD5 ratio of approximately 3.2. In the current version of the model, Kd was set to 0.1/day (and CBODu/CBOD5 was set to 2.54). This Kd was set through calibration and based on the consideration that the sole point source along the river discharges secondary treatment effluent, while the remainder of contributions are from the watershed (land) itself. In Lung, 2001, it is stated that in a river where secondary treatment effluent discharges and other sources are nonpoint source, the Kd can be as low as 0.075/day. Using a significantly higher Kd value would likely overestimate the impact of CBOD. |

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Surles, Tracy | 01-32 | Please include the phytoplankton monitoring data in the TMDL technical document. | The phytoplankton monitoring data are shown graphically on the plots in Appendix C of the TMDL report. A table has been added as per your request. |
| Surles, Tracy | 01-33 | Lacking a wetlands component in the model, does the sediment diagenesis model have to overcompensate the DO reduction associated with the sediment? | No, the sediment diagenesis model does not overcompensate the DO reduction associated with the sediment, because it only responds to the organic load coming into the river from the watershed and MOT. Some of the watershed contributions are expected to be trapped in the surrounding wetlands, however, no information was available to accurately quantify the influence of the wetlands. Therefore, the wetlands were not explicitly represented in the modeling framework. The entire watershed load generated by the GWLF model was input directly into the DYNHYD- WASP model as a conservative assumption. |
| Surles, Tracy | 01-34 | Please provide the monitoring data base and calculations that support the method by which the GWLF TN and TP outputs were converted to nitrate-nitrite, ammonium, organic nitrogen, orthophosphate and organic phosphorous loads. | Ratios among nutrient components (e.g., individual nitrogen components vs. total nitrogen) for boundary conditions in the existing DNREC model were used to convert the TN and TP outputs from the GWLF model into individual nutrient components. The ratios in the DNREC model were based on an analysis of water quality data. Although each modeling segment had been assigned a unique ratio in the DNREC model, the mean ratio of all segments was calculated and used to convert GWLF output into constituents for the WASP model. The final ratios used are presented on page 4-5 of the TMDL report. |
| Surles, Tracy | 01-35 | Please provide an explanation on how the CBODu/organic nitrogen, N/C and C/oxygen ratios were derived/selected. | The CBODu/organic nitrogen ratio (or C/N ratio) was determined through an iterative process, starting with the widely accepted Redfield Ratio, and then adjusting the initial value through calibration. The resulting CBODu/organic nitrogen ratio (or C/N) was twice as high as the Redfield ratio. This can be justified by the fact that the C:N ratio of overland organic matter can be as high as 4 to10 times the Redfield ratio (Lunsford, 2002). The ratio C/Oxygen=2.67 is a stoichiometry constant (Chapra, 1997). |

| Commentor | Letter ID | Comment | Response |
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| Surles, Tracy | 01-36 | Given that organic nitrogen represents 26.4% of TN generated by the GWLF, explain how it is reasonable to justify the high CBODu/organic nitrogen ratio by saying the organic nitrogen is relatively diminished. | When the report stated that "the organic nitrogen is relatively diminished", it meant that in comparison to carbon, nitrogen is relatively diminished (a small portion of organic matter is nitrogen). Although, organic nitrogen is a significant part of the total nitrogen load as mentioned in your comment it is not a significant portion of the total organic load which also includes organic carbon and phosphorous. This is consistent with the fact that the C:N ratio of the overland organic matter can be as high as 4 to10 times the Redfield ratio (Lunsford, 2002) |
| Surles, Tracy | 01-37 | For which dates during the calibration and validation period is monitoring data available? | Data are available for the following dates: 05/15/91, 06/20/91, 07/09/91, 08/12/91, 09/09/91, and 10/09/91. EPA has included this data in an appendix to the report. |
| Surles, Tracy | 01-38 | Why does the model not consider the loss of sediment due to high flow conditions? | The model is conservative in that it does not consider loss of sediment due to high flow conditions. This is part of the implicit Margin of Safety included in the loading. |
| Surles, Tracy | 01-39 | How does the model account for the oxygen depletion that occurs to the land-based flows as they pass through the marsh during the summer? | See response to 01-05. |
| Surles, Tracy | 01-40 | Why was GWLF trend: nutrient information used instead of instream water quality and flow measurements? | The GWLF model was used to predict watershed contributions over time, in order to generate inputs for the predictive sediment diagenesis model. In-stream measurements were used to test the model (through calibration and validation), however, they're insufficient to provide an accurate input time series for the sediment diagenesis model (because they are not reflective of a wide range of hydrologic conditions). The GWLF modeling framework also enables a source-based analysis and allocation to be made. |
| Surles, Tracy | 01-41 | If the model does not explicitly account for the impact of groundwater how can there be a base fresh water flow? In the absence of a net advective flow, the water below the dams would be saline.<br><br>Why then is the fresh water average criteria used for judging the model attainment and developing the TMDL? | The text in the report will be clarified. Groundwater contributions of flow and nutrients were predicted by the GWLF model, however, an explicit groundwater model was not implemented. In the absence of net advective flow, the salinity of the water below the dams would be dependent on salinity levels in Delaware Bay.<br><br>Please see responses to comment 3 |

| Commentor | Letter ID | Comment | Response |
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| Surles, Tracy | 01-42 | Please explain the enormous change in baseline TP between the 1998 model and the current draft TMDL. | The discrepancy between the 1998 and current model baseline TP values is attributed to two factors. First, the load used in the 1998 model was based on a low-flow condition, while the current model is based on variable hydrologic conditions (including all the actual storm events for the time period in addition to the low-flow conditions). Thus, the newly estimated load is expected to be significantly higher than the previous estimate. Second, the low phosphorus load estimated for the 1998 model was based on Ritter and Levin's method which uses an extremely high N:P ratio of approximately 57.0. The N:P ratio simulated by the GWLF model corresponds with the widely-accepted Redfield Ratio, which is less than 10.0. According to Wiseman, et al, 1999 (see reference list), the N:P load in watersheds should be close to the Redfield Ratio. Thus, this ratio was used as the basis for phosphorus predictions from the watershed. |
| Surles, Tracy | 01-43 | Please explicitly note that the TMDL does not limit the flow from the MOT plant. | The TMDL establishes a specific loading from the MOT facility. The permit for the MOT facility must reflect the loadings called for in the TMDL. If the permitting authority chooses to allow the flow from the facility to increase this would need to be compensated via a reduction in the discharge pollutant concentrations. |
| Surles, Tracy | 01-44 | Data are available for the particular sampling events, and the model produces output on a continuous basis, allowing direct comparison of the model with each data set. The TMDL compares averages of the model and data over several months. The model could be grossly in error on the high or low side of each sampling event. Even with the simplification several parameters in the calibration and verification sets don't agree with the model at all. | Data for the calibration and validation periods are not sufficient to perform an extremely detailed temporal and spatial calibration. Therefore, model calibration and validation results were evaluated through a comparison of the predicted and observed minimum, maximum, and average conditions during the period of interest (i.e., the time period used for evaluation of water quality criteria). The model results demonstrate that maximum and average concentrations, and in particular, minimum concentrations are predicted well. These minimum concentrations are the basis of the water quality criteria, and are thus the critical factor. |

| Commentor | Letter ID | Comment | Response |
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| Surles, Tracy | 01-45 | There appear to be several miscellaneous modeling problems. The DO upstream boundary concentrations were changes. For the calibration and validation periods, the boundary conditions were generated using the GWLF model. For the TMDL scenario, the DO concentration was assumed to be equivalent to 80% of the saturation level at a water temperature of 28 degree C. The effect of the above changes can best be evaluated by running the TMDL scenario with the input data in the calibration file. However this cannot be done at this time because the files provided to the County do not allow us to run the WASP model. The TMDL report does not provide details of the hydrodynamic calibration. From the input file, the May to July tidal data were recycled for the entire simulation period. Therefore it appears that the May to July tidal data have also been used for the validation period August to October. The validation seems to be questionable due to the use of tidal data of a different period. | In the calibration/validation periods, the DO boundary condition was set equal to the same values used in the previous DNREC model to maintain consistency (DO was not predicted by the GWLF model). These boundary conditions were not applicable to the TMDL run because when a nutrient/organic matter load reduction scheme is implemented, the DO concentration of the upstream incoming flow is expected to increase. Thus, 80% of the saturation level at a water temperature of 28 degree C was used as the boundary concentration in the TMDL case for DO. A more accurate set of tidal data may provide more confidence in the model validation, however, the quality of the validation is not expected to change significantly. Because the configuration and parameterization of the model is the same for both the calibration and validation period (i.e., no additional parameter adjustment was made for validation period), and the model predicted water quality well for the validation period using the recycled tidal data, it is reasonable to assume that the tidal data for the calibration period approximated conditions for the validation period reasonably well. |
| Stuhltrager, James | 02-01 | The Appoquinimink River TMDL is based on land use data form 1992. Because much of the pollutant loading to the River is contributed by nonpoint sources that are effected by land use, the TMDL may not accurately reflect current environmental conditions. As soon as more current land use data is available EPA should consider amending the TMDL to more accurately reflect current environmental conditions.<br><br>r | The draft Appoquinimink TMDL was based on 1992 land use data as stated in your comments. However, the model was run using the 2002 land use data EPA received during the comment period. This did not significantly change the TMDL as mentioned in the report. |

| Commentor | Letter ID | Comment | Response |
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| Stuhltrager, James | 02-02 | A potential source of additional pollutants is the future growth that is projected to occur in the communities surrounding the Appoquinimink River. The proposal does not consider the forecasted increase in both point and nonpoint source contributions due to the county's growth. The Appoquinimink TMDL should develop methods to control these future impacts before they adversely affect the River. | The water quality standard for the Appoquinimink River may be achieved through a variety of allocation scenarios. The TMDL provides one such scenario, which neither requires a reduction in the current point source loading from the MOT nor provides a specific allocation to future growth. DNREC retains significant discretion in implementing the TMDL. As implementation of the established TMDL proceeds, DNREC may find that the applicable water quality standard can be achieved through other combinations of point and nonpoint source allocations that are more feasible and/or cost effective. If that happens, DNREC is free to re-run the model and to propose a revised TMDL with a different allocation scenario that will achieve water quality standards. See response to 01-17. |
| Stuhltrager, James | 02-03 | The proposed TMDL is silent as to the methods that will implement the necessary load allocations. By failing to include a plan for implementation, the TMDL may not attain the applicable WQSs. | An implementation plan is not one of the regulatory requirements of a TMDL. Section 5.0 of the TMDL report describes the best management practices that have been put in place. |
| Stuhltrager, James | 02-04 | In the absence of any enforceable point source reductions, the Appoquinimink River TMDL must identify the specific BMPs that will be implemented and the corresponding NPS reduction that can be expected from each. | Many of the nonpoint sources are actually associated with New Castle County's MS4 permit, therefore there is a regulatory program established to address these loads. The specific BMPs which will lead to the 60% reduction in storm water loadings should be identified in the implementation plan which should be developed by the state. |
| Stuhltrager, James | 02-05 | EPA has failed to establish separate WLAs for the various MS4s in accordance with EPA regulations and guidance. | In the TMDL all nonpoint sources were placed in the WLA for the MS4 permit. The remaining loads from nonpoint sources will be placed in the WLA for the MS4 at this time the state and county are mapping out the storm sewer lines. Once this work has been completed the loadings from storm water will be further segregated. |
| Stuhltrager, James | 02-06 | The proposed TMDL does not include an adequate MOS. The MOS does not include foreseeable factors that should be considered in the proposal. It is recommended that EPA use an explicit MOS. | The TMDL uses an implicit MOS and conservative assumptions to account for uncertainties in the model. The conservative assumptions are identified in the TMDL report. |

# Appoquinimink TMDL Responsiveness Summary
# Dec. 15, 2003

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Worall, Courtney | 03-01 | If the deadline for the TMDL is extended, I highly recommend holding another public meeting to explain the new data and what changes, if any that results in. | The deadline for the TMDL is not being extend. |
| Worall, Courtney | 03-02 | Please provide data regarding the implementability of the 60% reduction in nonpoint source load allocations. | EPA does not have data on the implementability of the 60% reduction in stormwater loads to the Appoquinimink. EPA has provided information in the TMDL on common best management practices for stromwater management and the possible load reductions expected with these measures. |
| Worall, Courtney | 03-03 | The point source load allocation should remain as presented in the draft TMDL. | The point source allocation in the final TMDL is the same as what appeared in the draft TMDL. |
| Worall, Courtney | 03-04 | EPA should segrerate the storm water point sources from the nonpoint sources and assign discrete allocations after DNREC and the county complete their mapping effort. EPA should allow the public and the permitees to work together to determine how this segregation should take place. | The forest and agricultural loads that were placed in the WLA of the MS4 permit in the TMDL due to the resolution of the model and the data available. Future work between the state and county should be able to refine these loadings. |

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Myoda, Sam | 04-01 | DNRECs Division of Water Resources is concerned with the nonpoint source loading rates generated by the GWLF model and the inability to adequately calibrate and verify the resulting water quality predictions due to the lack of a comprehensive data set. In 1997, additional monitoring stations were added to provide a comprehensive coverage within the watershed. DWR believes that it is more appropriate to use a post 1997 data set so that the model may be adequately calibrated and verified. In addition the use of the more recent data set would better reflect the current conditions in the watershed, eliminating the need ro adjust the proposed load reductions to reflect those reductions that have occurred since 1991. | Although a comprehensive water quality data set for the headwaters of the Appoquinimink River watershed was not available to perform a detailed calibration of the GWLF model, constituent loadings predicted by the model were validated through comparison of the WASP model predictions to monitoring data. The WASP model used GWLF model results as inputs. Thus, in order for the WASP model to accurately predict nutrient, DO, and algae levels, it was necessary for the GWLF loadings to be reasonably accurate. Because the WASP model results correlated well with monitoring data, the GWLF loadings can be assumed to be reasonable. Additional monitoring data in the headwaters would support refining the GWLF model calibration, however it's possible that load estimates would not differ from the current predictions.<br><br>At the time the updated model was calibrated, only the MRLC landuse coverage (early 1990s) was available, therefore the 1991 time period was used for model calibration. Additionally, calibration of the receiving water model (WASP) focused on adjusting kinetic parameters that likely would not change significantly from the early 1990s to current conditions. The in-stream processes and relationships are not expected to change with changes to terrestrial land uses. Thus, the actual calibration year is not necessarily a critical factor. The primary changes would come in the land- based contributions (i.e., predictions from the GWLF model). Because the GWLF model is a dynamic, predictive watershed model that is source/landuse-based, it can readily be updated to reflect current conditions without the need for a full calibration. That is, the landuse distribution in the model can be updated to reflect current conditions, and new loadings can be predicted and applied to the receiving water model (without necessarily the need for recalibration. |

| Commentor | Letter ID | Comment | Response |
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| Myoda, Sam | 04-02 | The GWLF output calculated the annual phosphorous load to be substantially higher than Ritter and Levin's rates. DWR monitored the outflows at Silver Lake and Noxontown Lake to determine actual nonpoint source loads to the upper boundary of the tidal river to serve as a basis for Ritter and Levin's calculations. This discrepancy needs to be addressed. | The discrepancy is attributed to two factors. First, the load used in the 1998 model was based on a low-flow condition, while the current model is based on variable hydrologic conditions (including all the actual storm events for the time period in addition to the low-flow conditions). Thus, the newly estimated load is expected to be significantly higher than the previous estimate. Second, the low phosphorus load estimated for the 1998 model was based on Ritter and Levin=s method which uses an extremely high N:P ratio of approximately 57.0. The N:P ratio simulated by the GWLF model corresponds with the widely-accepted Redfield Ratio, which is less than 10.0. According to Wiseman, et al, 1999 (see reference list), the N:P load in watersheds should be close to the Redfield Ratio. The Redfield Ratio is based on terrestrial sources which are the sources being recreated in the model and therefore the Redfield Ratio was deemed appropriate. Thus, this ratio was used as the basis for phosphorus predictions from the watershed. |
| Myoda, Sam | 04-03 | DWR's Surface Water Discharges section issues NPDES permits based on 7Q10 flow conditions. The dynamic model looks at a seasonal average and may overlook the critical periods. The steady state model used in the 1998 TMDL is more consistent with the 7Q10 and critical time period approach. DWR supports the EPA in recognizing that the point source waste loads will be maintained at their existing level. | The model used for TMDL development does not look at seasonal average conditions. It makes predictions at a sub-hourly timestep for the entire modeling period. Therefore, it predicts constituent levels for low-flow as well as for storm events. More importantly, the model makes predictions for critical conditions overlooked by a 7Q10 analysis (e.g., relatively low- flow conditions that follow a storm event). A 7Q10 analysis assumes minimal land-based loading inputs, however, these inputs (which are typically contributed during storm events) become the most critical factor even during low flow events, such as the 7Q10. Thus, the current modeling framework can be used to evaluate critical periods in more detail than a steady-state 7Q10 evaluation. |
| Myoda, Sam | 04-04 | At this time neither EPA nor DWR has sufficient data to determine the portion of water that is captured by the storm water system. DWR supports EPA in combining the WLAs for the storm water permits and the Las for the areas not covered by the storm water permits until adequate dat is obtained ro justify a discrete allocation to the storm water permits. | The forest and agricultural loads that were placed in the WLA of the MS4 permit in the draft TMDL can now be found in the LA. The remainder of the storm water loading has been lumped into one gross WLA for the MS4. EPA believes that the state, stakeholders, and permittees should further segregate this loading when the storm sewer mapping data set becomes available. |

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Myoda, Sam | 04-05 | The adjusted CBODu/CBOD5 ratio is significantly higher than monitoring data values. | There were no CBODu/CBOD5 data available during the study. Only CBOD20 was measured, as indicated in the dataset. The CBODu/CBOD5 ratio in the current version of the model was determined based on the CBOD decay rate of 0.1/day. In general, a high CBODu/CBOD5 ratio is associated with a low CBOD decay rate, which indicates that the organic matter in the water is relatively well stabilized and would impose less impact on the DO concentration. See Comment 1-31 for additional discussion on the CBOD rate. |
| Myoda, Sam | 04-06 | SOD is one of the major drivers affecting the DO levels in the Appoquinimink River, using this approach, and with a CBODu/CBOD5 ratio that DWR considers too high, the SOD values may also be too high, resulting in reductions that are greater than necessary to ensure State Water Quality Standards are met. | No in-situ SOD data were available for directly calibrating the sediment diagenesis model during the study. However, the predictive sediment diagenesis model was indirectly calibrated and validated through a comparison of the simulated DO, NH3 and PO4 concentrations with monitoring data. If the SOD, NH3 and PO4 fluxes simulated by the sediment diagenesis model were incorrect, then the water column DO, NH3 and PO4 would not have matched the monitoring data. Since model predictions for these constituents correlated well with monitoring data, this is not the case. The CBODu/CBOD5 does not have a significant impact on the predicted SOD value because the major source of organic matter that generates SOD is from the watershed (land-based) loading (where the CBODu/CBOD5 ratio does not play any role). Thus, the proposed reduction to meet the State WQS was not caused by the high CBODu/CBOD5 ratio. |
| Myoda, Sam | 04-07 | Total nitrogen is not considered only Total TKN. DWR would ask that EPA to consider a WLA for nitrogen that exists as nitrate and nitrite. | The WLA assigned for the MOT WWTP NPDES discharge (DE0050547) included only TKN, in order to be consistent with its current permit. |
| Bryan, Frank & Rhoda | 05-01 | Do not increase the WLA for New Castle County Water Farm #1. | The point source allocation in the final TMDL is the same as what appeared in the draft TMDL |
| Murray, Joseph | 06-01 | Do not increase the WLA for New Castle County Water Farm #1. | The point source allocation in the final TMDL is the same as what appeared in the draft TMDL. |

# Appoquinimink TMDL Responsiveness Summary
# Dec. 15, 2003

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Love, Susan | 07-01 | No reductions are called for in the load from the MOT wastewater treatment plant. The plant is currently in violation of its permit and trying to reduce its buffer requirements order to accept more flow per day. It is unclear how the load reduction of 60% will be accomplished. While it is understood that nonpoint source pollution is a major factor in the impairment of the Appoquinimink River, clean water quality gains can be made immediately by reducing the allowable nutrient contributions of the MOT plant. | Your comments regarding the performance of the MOT facility will be forwarded to DNREC and EPA's enforcement branch. As stated in your comments the TMDL calls for a 60% reduction from land based sources yet does not require a reduction in the MOT effluent. The TMDL model found that Appoquinimink was more sensitive to reductions in land based sources of nutrients. These sources represented over 90% of the nutrient load and must be reduced for the River to attain the applicable criteria. |
| Lang, Bryan&Rebecca | 08-01 | Do not increase the WLA for New Castle County Water Farm #1. | The point source allocation in the final TMDL is the same as what appeared in the draft TMDL |
| Whiteside, Warren | 09-01 | Do not increase the WLA for New Castle County Water Farm #1. | The point source allocation in the final TMDL is the same as what appeared in the draft TMDL |
| Mulholland, Chuck | 10-01 | We have learned of that New Castle County has approached EPA to increase their discharge in the Appoquinimink River from 0.5 mgd to 2.5 mgd without any prior advisory from our local government. We believe that a reduction from a single point source, the waterfarm, would more easily attain the water quality we seek to attain. | New Castle County did propose that the WLA from the MOT plant include an increase in its current loading . EPA ran the model with the increased WLA to the MOT plant and predicted that this increase in the loading from the MOT plant would cause a failure to achieve water quality standards. Thus, the allocation scenario selected for the TMDL provides for no change from the current loading from the MOT plant. The TMDL model found that Appoquinimink was more sensitive to reductions in land based sources of nutrients. These sources represented over 90% of the nutrient load and must be reduced for the River to attain the applicable criteria. According to the model, the River would be unable to attain the applicable criteria even if the MOT facility was removed. It should be noted that the TMDL provides only one allocation scenario. DNREC retains significant discretion in implementing the TMDL. As implementation of the established TMDL proceeds, DNREC may find that the applicable water quality standard can be achieved through other combinations of point and nonpoint source allocations that are more feasible and/or cost effective. If that happens, DNREC is free to re-run the model and to propose a revised TMDL with a different allocation scenario that will achieve water quality standards. See response to 01-17. |

# Appoquinimink TMDL Responsiveness Summary
# Dec. 15, 2003

| Commentor | Letter ID | Comment | Response |
|---|---|---|---|
| Waxman, Harry | 11-01 | Do not increase the WLA for New Castle County Water Farm #1. | The point source allocation in the final TMDL is the same as what appeared in the draft TMDL. The WLA was not increased for the MOT facility. |
| Chandler, David | 12-01 | Do not increase the WLA for New Castle County Water Farm #1. | The point source allocation in the final TMDL is the same as what appeared in the draft TMDL. The WLA was not increased for the MOT facility. |
| Baker, Bob | 13-01 | As a result of the "Hawes Case", the EPA and the State of Delaware should stop the process of developing TMDLs. The Court found that the agreement with the State of Oregon was null and void and that the state should stop imposing and implementing TMDLs on nonpoint source waters. | To the extent the commenter is arguing that the Clean Water Act does not authorize EPA to establish TMDLs where the sources of the pollutant loadings are nonpoint sources, the commenter is incorrect. In Pronsolino v. Nastri, 291 F.3d 1123 (9th Cir. 2002), cert. denied, 123 S.Ct. 2573 (2003), the U.S. Court of Appeals for the Ninth Circuit held that the Clean Water Act authorizes EPA to establish TMDLs for waters that are impaired by nonpoint sources. |

# APPENDIX B

# Appoquinimink River Association and Appoquinimink Tributary Action Team's Recommended Appoquinimink Pollution Control Strategy

25 March 2005

## Overview

The Delaware Department of Natural Resources and Environmental Control (DNREC) approached the Appoquinimink School District's Science Curriculum Coordinator in order to solicit her assistance in forming and facilitating a Tributary Action Team (Team) for the Appoquinimink watershed. This Team was tasked with recommending a Pollution Control Strategy (PCS) to DNREC for meeting the nutrient and dissolved oxygen Total Maximum Daily Loads (TMDLs) established by EPA in January 1998 (for the tidal portion) and to meet the future TMDLs (for the tributaries). In December 2003, another TMDL was established by EPA that included the entire watershed and required a more stringent reduction in nutrient loads. With the creation of the nonprofit organization the Appoquinimink River Association in April 2004 by members of the Team, they too became involved with creating additional recommendations to help strengthen the Pollution Control Strategy. This document includes the Team and Association's recommendations for that strategy.

This PCS recommends actions which will work towards achieving a 60% reduction in nonpoint source nutrient loadings to the River and its tributaries. It is based upon the guiding principles that were gleaned from a June 2001 public forum as well as meetings of the Association's Pollution Control Strategy Subcommittee in 2004 and 2005. The PCS is divided into four major issues: development, wastewater, residential behaviors, and agriculture.

The following guiding principles were discussed and agreed upon during the June 2001 public forum. These principles served to guide the writing of the actions within the Pollution Control Strategy.

## GUIDING PRINCIPLES

- Concurrence of all applicable laws, regulations and ordinances are needed to achieve the TMDL.
- Regulation must be fair and reasonable; rules must apply to everyone equally.
- Watershed residents need to be informed as to the problems and solutions of water quality. (education)
- Participation by residents will be necessary in order to achieve the required nutrient reductions.
- We need to use a combination of policy and management tools in the PCS.
- There needs to be a mechanism in place that measures progress towards achieving water quality goals and communicates it to the public at regular intervals.

## POLLUTION CONTROL STRATEGY

The following are the actions that we recommend be taken in order to achieve the TMDL for the Appoquinimink River. This Pollution Control Strategy (PCS) addresses issues related to the various types of land use within our watershed—development, wastewater, residential behavior and agriculture. The PCS will impact all levels of government—State, County, and Municipalities. The recommendations tackle planning issues, design and implementation of best management practices as well as corrective measures that can be taken in order to reduce nutrient loading to the River and its tributaries. These issues are listed in alphabetical order and do not reflect priorities.

### Agriculture

- In order to further the TMDL goals for the Appoquinimink watershed, the State should encourage participation by anyone that will be covered by the Nutrient Management Act to implement a Nutrient Management Plan prior to mandatory compliance. The State should continue to responsibly fund nutrient management planning and implementation.

- The County and State should coordinate their efforts to preserve farmland in the Appoquinimink watershed. These lands provide water quality and quantity benefits when farmed responsibly. If the County decides to move forward without the State, this program should be a priority.

- The Team supports a recognition program for farmers in the Appoquinimink watershed who do the most to protect water quality.

### Development

The State should promulgate minimum standards for nutrient reduction as they relate to development. The County and municipalities must enact ordinances that will at least achieve those standards within one year of the promulgation of the PCS.

*Conservation design*

- Given that the County is working with State agencies to better implement conservation design principles, the Team encourages these governmental bodies to define the concept of “conservation design” and to enact codes and regulations that allow for and promote “conservation design” principles with the goal of reducing nutrient loads.
  - Conservation design principles include practices that reduce surface water runoff of nutrients, such as promoting: infiltration, narrower roads and sidewalks, swales and grassed waterways, water use conservation, recycling, natural resource protection, open space preservation, and park creation, among other practices. Lot size and density considerations should also be included in conservation design plans.
  - The Team also asks that governments include citizen input by having the Team represented during their discussions.

- Municipalities shall have similar ordinances that meet or exceed the watershed protective properties of those ordinances passed by the County.

- These governments shall coordinate efforts to provide an on-going education and outreach program for communities in order to help maintain the elements of their community design.

*Stormwater*

- Local governments (municipalities and the County) will establish, or increase capacity of, a community stormwater runoff education and maintenance program for the watershed. This program will provide resources to educate homeowner maintenance organizations (HMOs) and other groups maintaining stormwater structures and design on their proper maintenance. Inspections shall be carried out as required. While this is a local government function, DNREC shall provide guidelines, technical standards and assistance.

- Within 6 months from the promulgation of the PCS, DNREC shall convene a group composed of Municipal, County and State government, and community representatives who shall establish a stormwater retrofit process for the Appoquinimink watershed.
  - This program will use monitoring data (DNREC) to prioritize areas where current stormwater treatment does not optimally remove nutrients and bacteria associated with those nutrient loads.
  - A schedule shall be developed for the retrofitting of these stormwater structures based on the priority ranking.
  - Funding for these retrofits shall come from multiple sources.

- All permanent sediment and stormwater management plans shall be designed and implemented to include design criteria that will reduce nutrient loading by the percentage required to meet TMDL required nutrient load reductions of ground and surface waters to the maximum extent practicable.
  - The percent reductions shall be based on a comparison between the post-developed condition with and without stormwater quality management best management practices.

- Encourage the creation of a stormwater utility pilot project in the Appoquinimink Watershed.

- Where feasible, encourage County and municipal governments and agencies to fast-track innovative stormwater management techniques and designs for implementation where appropriate.

*Impervious cover limits*

- The State should promulgate a watershed-wide limit for impervious coverage with consideration for site-specific mitigation.

- The Appoquinimink Tributary Action Team recommends that the State adopt regulations for the Appoquinimink watershed restricting development in Water Resource Protection Areas at least as strict as those in the New Castle County Unified Development Code

(UDC). These limits should include an impervious coverage limit of 20% in all Water Resource Protection Areas, limiting building to 50% of the site.

- The State, Municipalities, and the County shall decrease the maximum permitted percentage of impervious cover in areas where soil type, ground water recharge, and other factors dictate that pervious areas are needed to prevent nutrient over enrichment of nearby surface waters. DNREC will determine those factors.

- Suggestions and incentives for use of alternative pervious materials and strategies (to take the place of traditional impervious ones) for sidewalks, parking lots and roadways will also be provided to developers by all governmental entities. Once the parcel reaches 12% impervious coverage, these entities will require the use of these alternative pervious materials and strategies.

*Open Space*

- All open space land uses shall be designed and managed for water quality protection, including reduced nutrient loading. Reforestation, meadow development, wetlands construction, etc., shall be encouraged through increased outreach efforts by the appropriate jurisdictions and the Appoquinimink watershed coordinator (see below).

- Early implementation of the Nutrient Management Act for turf management over 10 acres shall be encouraged.

- The State, County and local governments should develop guidelines to maintain community open space.

- Programs such as the NRCS cost-share efforts and other incentive efforts should be better publicized to residents and maintenance corporations in order to support enhancement of the open spaces they manage.

*Land Disturbing Activities*

- With non-agricultural land disturbing activities in excess of 5,000 square feet, a nutrient budget must be produced.
  - This budget, based on the best available data, shall illustrate the current nutrient loading of that area to ground and surface water and the proposed nutrient loading from the new use. The nutrient budget must illustrate that the future land use will reduce nutrient loading by the percentage required to meet TMDL nutrient load reductions for the waterbody in which watershed the particular location exists. DNREC and its delegated agencies shall not issue any water quality related permit for an area unless a submitted and approved nutrient budget shows that the area will achieve the TMDL nutrient load reductions once the construction or changes are complete.

<u>Residential Behavior</u>

- Establish guidelines that promote good lawn and yard stewardship through best management practices, including organic methods of care, for better nutrient management and water quality. These guidelines should be disseminated throughout the watershed by DNREC and the Department of Agriculture. Brochures could be placed in stores that sell yard materials, restaurants, and in other public places and passed out at community events.

- The State should work with the University of Delaware Soils Lab to revise the soil test result sheets that go to homeowners in order to make them more understandable and easily implemented by the lay public. The State should also work with the Cooperative Extension Service to assist in disseminating soil test kits.

- The State and local governments should develop appropriate code changes and distribute guidelines for alternative lot landscaping that will reduce surface water runoff, etc. Information should be given to homeowners at the time of settlement.

- Explore the possibility of providing nutrient management education and training for those who sell fertilizers in retail outlets. The State should require that a stick-on label be placed on all bags of fertilizers sold in the watershed. The label should contain a warning in large letters that the overuse or improper use of fertilizers and pesticides harms our ground and surface waters. The label should be printed in English and Spanish. The label should state that fertilizer should not be applied when rain is expected and it should supply reasoning to support warning.

- All environmental information should be supplied periodically on the scrolling band under the picture on the Weather Channel. DNREC should find the money to pay for this if cable providers will not do it as a public service.

## Wastewater

*Inspection/replacement*

- The County and State should initiate as required by the UDC a septic system compliance program, which unifies both State permit requirements and UDC inspection provisions. This action would lead to the replacement and/or the repair of failing systems within the watershed.

- The State shall use this watershed as the area for a pilot program for septic system inspection in New Castle County. Under the pilot program, the county's tax bill mailing could be used to inform the owner of a septic system that their system needs to be inspected and that a certificate of inspection must be submitted when tax bill is paid.

- Seepage pits, cesspools and permanent holding tanks should be prohibited within the watershed.

- Convert as many lots as feasible (of less than 2 acres each) currently on septic to sewer connection in an equitable manner whereby those systems of high priority and feasibility (where there is already infrastructure in place) are converted first.
  - The State and DNREC should provide cost share and grant monies to these homeowners to help offset costs.

*Compliance*

- Legislation should be passed that will authorize the DNREC to license septic system inspectors, an action that will support the compliance program.

- The legislature should amend real estate law to require, at the time of sale, certification that the septic system is properly functioning or that the system has been inspected under the compliance program within six months of the pending sale and a three-year written system history of maintenance. An education brochure on proper maintenance should also be provided at the time of sale.

- The State and County should work together to develop and disseminate homeowner education materials. The materials should inform septic system owners about maintaining their septic systems, based on the system type that they use (cesspools, holding tanks, septic tank, sewer), such that nutrient loading from the system is minimized. The materials should emphasize the benefits to the homeowner and the watershed of maintaining their septic systems.

- All new and replacement subdivisions, as defined by Delaware Code, in areas outside a legally established county sewer district shall be equipped with either individual onsite systems that meet TMDL required nutrient load reductions or best available technology nutrient load reductions OR a community system that utilizes technologies which meet TMDL required nutrient load reductions or best available technology nutrient load reductions.

*Alternative Systems*

- The Team also encourages the scientific monitoring of standard and alternative septic systems to determine whether alternative systems further reduce nutrient discharge.

- Whereas septic systems contribute nutrients to the watershed, the Team recommends the use of wastewater treatment systems that reduce nutrients. These systems should use the most effective technology to reduce nutrient loading. Large community systems are preferred to individual septic systems.

## Future Needs

- There is a need for education on BMPs and an aggressive marketing program that promotes and helps fund them in the Appoquinimink watershed. The Team believes that an Appoquinimink watershed coordinator and BMP advocate should be hired to assist efforts in reducing nutrients using funds from various sources.

- We encourage both the County and State to re-establish a groundwater-monitoring program for southern New Castle County to ensure the quality of our drinking and surface water.

- The Team recognizes the potential value of forming a citizen’s organization for the benefit of the Appoquinimink watershed.

# APPENDIX C

# Public Talk – Real Choices: A Model for Public Engagement in Creating Pollution Control Strategies

Bill McGowan[1], Joe Farrell[2], Ed Lewandowski[3], Kathy Bunting-Howarth[4], Lyle Jones[5]

## *Introduction*

Public issues are complex, 'wicked' problems. Poverty, education, land-use, environment and others are issues not easily resolved. Delaware for example is a national leader in welfare reform, education reform, land use legislation and the environment but those close to these issues know the reforms are stalled locally and nationally. Why? We believe a lack of public engagement in creating public policy is a fundamental reason. We have become a technocratic society, resulting in the public abdicating it's role as participants in creating public policy to a bureaucracy. It is generally accepted by both parties, the public and bureaucracy, that the public does "not have the capacity" to work through complex issues. It is incumbent on those who work with the public to create a better way to engage the public in creating sustainable public policy.

## *A Common Model for Public Engagement*

One model found frequently when public agencies need public input is the "workshop" model. The model begins with a selection of a small group of people, a citizens advisory committee or "blue ribbon" panel. The group, usually with the help of the public agency, goes through an education process, writes a report, and delivers it to the agency. The agency holds "tell and sell" workshops, followed by public hearings and possible promulgation of regulation. The model more often than not fails to give the public a significant chance to participate in policy formation, resulting in disillusionment, and failed policy. Both the public and public agencies need and deserve a better way to work together that produces sustainable decisions.

## A Preliminary Approach

*Losing Ground: What Will We Do About Delaware's Changing Landscape?* A series of issue forums or public conversations, throughout the state in 1996, introduced deliberative dialogue to 340 Delawareans. Deliberative Dialogue is a conversation in which people, the public, weigh the cost and consequences of their thinking and make choices based on their deliberations. It was the first time for many where in a public meeting citizens had the opportunity to both listen and talk to each other in an environment conducive to learning. It was not a public hearing where comments are taken for the record or workshop with information presented by experts. Comments after the forums indicated citizens would come out and discuss issues of importance, people want a way to engage issues personally, and will engage each other in questioning and learning. The results of *Losing Ground* appear to indicate the public wants a better model to engage public issues. It is from the conversations heard from citizens that participated in *Losing Ground* that the model *Public Talk – Real Choices* emerged.

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## *Why Develop Another Model?*

Two major citizen efforts assisted by DNREC, the Inland Bays Monitoring Committee and the Citizens Advisory Committee of the National Estuary Program, produced action plans for restoration of the Inland Bays. The plans are very similar to each other, in fact a matrix of the two plans attempts to avoid duplication of effort (CCMP, 1995). Citizens spent over nine years of work between the two plans. Both plans emerged from a visioning model asking the questions “What do we want the Bays to look like?” and “How can we get there?” The action plans are broad recommendations that lack specific suggestions for implementation. There remains a tremendous amount of frustration from citizens who have engaged in one or the other or both of the Bay protection efforts (Citizen Advisory Committee Minutes, 1997) and the public agency, DNREC, whose mission is to preserve and protect the natural resources of Delaware. Both parties want the same thing, healthy bays, and still there is no solution or commitment.

### A Caveat

There is a difference between then and now and that is TMDL’s are regulations. Both the Inland Bays Monitoring Committee and the National Estuary Program were voluntary. The regulatory community can argue TMDL’s are promulgated regulation that demand action through pollution control strategies. That is true to a point. The State met the requirement of the settlement by establishing the TMDL’s for the watershed. The pollution control strategies are self-imposed requirements. Without significant public engagement in creating strategies that potentially impact all residents in the watershed, the strategies will die in the political arena. By taking time on the front end, and working through a truly public process, the State stands to gain more in the end product of a sustainable public policy.

## *The Model: Public Talk – Real Choices*

The purpose of *Public Talk – Real Choices* is to move formulation and creation of a major public policy decision from a public agency to the public for dialogue and deliberation. *Public Talk – Real Choices* builds on what happened in *Losing Ground* forums. Using deliberative dialogue as the core, *Public Talk* goes further by engaging the public in learning about the issue, weighing the costs and consequences of what is important through dialogue with each other, and coming to public judgment. The model consists of six steps; Organization of Work Team, Education, Issue Framing, Evaluation of the Issue Framework, Public Forums/Choice Work, Recommendations.

### Model Components

**Organization -** is a structural component that brings the public agency and public, the work team, into agreement as to what needs to be accomplished. Without preliminary understanding and agreement by both parties, the effort will fail. **Education -** further enhances this arrangement by building upon the knowledge of the process shared in the organizational discussions and then adding information necessary to frame the issue. A good portion of technical information will come from the public agency e.g. the Inland Bays Whole Basin Assessment Report.

**Issue framing -** is the critical piece necessary for public engagement. Issue framing lays out in an organized fashion for public consumption three or four choices. The framework must be unbiased, represent the under girding values embedded in policy choices and articulate the basic costs and consequences of the choices. It should represent the voices of all impacted by the issue.

The framework sets the stage for our conflicting motives – those things we consider valuable and that pull us in different directions when we have to decide how to act. The issues need to be stated in ways that compel the public to make their views known.

**Evaluation of the Framework -** This piece gives insight into how successfully the teams framed the issue. The use internal deliberation, focus groups, etc. enhances the success of the framework. For successful public deliberation all voices need to heard within the framework. The choices must be neutral and offer a positive approach for issue resolution.

**Public deliberation -** is the cornerstone *of Public Talk – Real Choices*. A significant representation of the public must deliberate the issue. This occurs through successful planning and selection of venues for forums. The forums must result in some form of common ground for action.

**Recommendations -** The work teams sift through and analyses the public voice they heard from the forums. From this public voice the work team develops the pollution control strategies.

## *Why This Model?*

### National Issues Forums

National Issues forums are "town meetings" that bring people together to deliberate "wicked problems," problems that won't go away, with the help of moderator. The medical analogy of a broken arm versus diabetes describes wicked problems. The broken arm can be set and heals. Diabetes requires life -changing alterations. Participants use an issue book that offers three to four choices for resolution. Within the choices are basic values, cost and consequences of the choice. With the help of a moderator the public works through the choices, by looking at four things: What is valuable? What are the costs and consequences of the choice? Where is the tension? Where is there common ground for action? Participants must consider "It's not what I want to do but what we ought to do."

### Why Are These Models Effective?

The Harwood Group in a report *Meaningful Chaos- How People Form Relationships with Public Concerns*, found nine factors necessary for public engagement.

**Connections** – People tend to enlarge rather than narrow their views of public concerns, making connections among ideas and topics that society tends to fragment.

**Personal Context** – People relate to concerns that "fit" with their personal context, moving beyond self-interest to what is meaningful

**Coherence** – People want to hear the whole story. They want to understand what it means.

**Room for Ambivalence** – People do not immediately see black and white. They want a gray area to question, discuss, test ideas, and become comfortable with their opinions.

**Emotion** – Too many processes try to remove emotion from decisionmaking. Emotions are necessary to sustain relationships with public concerns.

**Authenticity** – People and information must "ring true".

**Sense of Possibilities** – People really want something to happen and they might play a role in it.

**Catalysts** – Everyday people, not just experts and elite, are critical in helping people form relationships with public issues.

**Mediating Institutions** – Places where people come together to talk and act on public concerns. (Harwood, 1993)

*National Issues Forums* and *Public Talk – Real Choices* adhere to these tenets.

## *The Facilitator Team*

*Public Talk – Real Choices* uses a neutral, third party facilitator. By using a neutral, third party as the facilitator, the facilitator becomes an advocate for the process (Kaner, 1996). Third party facilitation avoids the perception of bias that can occur when the facilitator is personally associated with the issue.

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# APPENDIX D

# BMP NUTRIENT REDUCTION CALCULATIONS

## Calculating the Required Total Maximum Daily Load Reductions Based on Land-use

The Total Maximum Daily Load (TMDL) for receiving waters in the Appoquinimink calls for a 60% reduction in total nitrogen (TN) and total phosphorus (TP) (EPA, 2003). The baseline period for this TMDL was established from 1992 land use data used to determine the acreages of each of the following land uses: Urban, Agricultural, Forest, Wetland, Water, and Other, which includes land uses like rangeland and barren land. The results are tabulated below (Table 1).

**Table 1. 1992 Appoquinimink Watershed Land-use Acreages**

| Urban | Agricultural | Forest | Wetland | Water | Other | Total acreage |
|---|---|---|---|---|---|---|
| 3,156 | 18,556 | 2,677 | 3,769 | 1,117 | 389 | 29,664 |

In order to calculate nutrient loads from non-point pollution sources, the land use acreages from Table 1 were combined with the land use loading rates in Table 2, which were determined based on results of research conducted by experts in the Appoquinimink Watershed to produce daily nutrient loads according to land use, as displayed in Table 3.

**Table 2. Land-use Loading Rates**

| | TN (lbs/acre/yr) | TP (lbs/acre/yr) | Source |
|---|---|---|---|
| **Developed** | 15.0 | 0.48 | Ritter and Levan (1992) average of high and low density |
| **Agriculture** | 25.0 | 0.60 | Ritter and Levan (1992) |
| **Grasslands** | 10.0 | 0.40 | Ritter and Levan (1992) |
| **Forests** | 5.0 | 0.25 | Ritter and Levan (1992) |
| **Wetlands** | 0.0 | 0.00 | Ritter and Levan (1992) |
| **Water** | 12.0 | 0.75 | Ritter and Levan (1992) |
| **Other** | 10.0 | 0.40 | Ritter and Levan (1992) |

| Table 3. 1992 Appoquinimink Watershed Land-use Based Loads | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Urban** | **Agricultural** | **Forest** | **Wetland** | **Water** | **Other** | **Total** |
| **TN (lbs/day)** | 129.70 | 1,270.96 | 36.67 | 0.00 | 36.72 | 10.66 | **1,484.71** |
| **TP (lbs/day)** | 4.11 | 30.50 | 1.83 | 0.00 | 2.30 | 0.43 | **39.17** |

## I. Baseline load calculation for land-use type by reduction area:

Using the land use loading rates listed in Table 2, the nutrient loads coming from non-point sources during the baseline period are determined using the equation below. It should be noted that the grassland loading rate was used to determine the loads from the "Other" land use category.

| Nutrient load lbs/yr & lbs/day (Table 3) | = | Acreage of specific land-use (Table 1) | x | Loading rate for specific land-use (lbs/acre/yr) (Table 2) |
|---|---|---|---|---|

EX: TN load for urban land use:

| TN load | = | 3,156 acres | x | 15 lbs TN/acre/yr | = | **47,340 lbs TN/yr or 129.70 lbs TN/day** |
|---|---|---|---|---|---|---|

## II. Required TMDL reduction on a land-use basis:

The annual and daily nutrient load reductions needed from non-point sources to achieve the reductions outlined in the TMDL are calculated using the following equation. For the Appoquinimink Watershed, the TN load needs to be reduced by 890.83 lbs/day and the TP load by 23.50 lbs/day. In order to achieve these reductions, the best management practices (BMPs) discussed in the Pollution Control Strategy must be implemented.

| Required TMDL reduction (lb/day) | = | Baseline load (lb/day) | x | Percent reduction |
|---|---|---|---|---|

EX: TN TMDL required load reduction:

| Required TMDL reduction (lb/day) | = | 1,484.71 lbs TN/day | x | 60% | = | **890.83 lbs TN/day** |
|---|---|---|---|---|---|---|

## Onsite Wastewater Disposal System (OWTDS) BMP Calculations

In order to determine the nutrient loading by OWTDS to groundwater, local watershed data and knowledge has been utilized.

Twelve OWTDS existing near Red Mill Pond in Lewes, Delaware were monitored in 1993 (DNREC, 1994). The average total phosphorus concentration of the effluent from these systems was 15.7 mg/L, while the total kjeldahl nitrogen (TKN) concentration was 58.5 mg/L and the nitrate/nitrite concentration was 0.8 mg/L. The total nitrogen concentration of the average effluent from this study was summed to equal 59.3 mg/L. Conversations with professionals in this industry have suggested that 50.0 mg/L is a more appropriate value of TN concentrations in on-site effluent and this value has been used in subsequent calculations.

Small systems, which are typical individual household systems, have flows less than 2,500 gpd. The average design flow for individual residential OWTDS is 221 gpd.

The nutrient load to the watershed from drain fields can be established by determining the product of the above concentrations and respective flow rates.

Robertson and Hartman (1999) found that 85% of the total phosphorous in the effluent will be retained in the vadose zone or the unsaturated soil above the water table, most of which is within 12 inches of the drain field (Gold and Sims, 2000). Initial calculations presented by the Department, also based on the Red Mill Pond study, assumed that 87% of TP and 52% of TN is assimilated in the soils once the effluent leaves the septic tank.

The final loading rates from OWTDS to groundwater can be determined using the following equations:

Small systems (<2,500 gpd):
[Conc. (mg/l) x (lb/453,592 mg)] x [(221 gal/system/day) x (3.7854 l/gal)] x (1-soil assimilative capacity)

Thus, the OWTDS nutrient loading rates to groundwater in the Appoquinimink Watershed are:

- 0.052 lbs TN/system/day and 0.004 lbs TP/system/day for individual small systems less than 2,500 gpd

## I. Connecting OWTDS to Sewer Districts

Since 1992, 11 OWTDS (septic) systems are reported to have been removed from the Appoquinimink watershed by connecting homes and businesses to sewer districts ((New Castle County Special Services, written communication, 2009) and (Town of Middletown, written communication, 2009)). These systems have been connected to sewer districts that dispose of their waste at spray irrigation facilities.

Reductions for systems that are connected to plants that use spray irrigation receive a 90% efficiency since nutrients remain in the ecosystem (DNREC Groundwater Discharges Section, personal communication, 2003). The nutrient load reductions are calculated using the following equation.

| Nutrient load reduction (lbs/day) | = | OWTDS loading rate (lbs/system/day) | x | # of eliminated OWTDS | x | Reduction efficiency |
|---|---|---|---|---|---|---|

EX: TN reduction due to OWTDS connection:

| TN load reduction (lbs/day) | = | 0.052 lbs TN/system/ day | x | 11 eliminated OWTDS | x | 90% | = | **0.52 lbs TN/day** |
|---|---|---|---|---|---|---|---|---|

## II. <u>Holding Tank Inspection and Compliance Program</u>

On average, holding tanks have a 2,800 gallon capacity. Metcalf and Eddy (1991) reported that holding tanks typically hold 2,596 gallons of effluent and 204 gallons of septage (solids). Recent observations from the compliance program indicate volumes of 2,464 gallons of effluent and 336 gallons of septage volume. The average effluent concentrations previously discussed (50.0 mg TN/L and 15.7 mg TP/L) have been used to determine the effluent loads from holding tanks. The nutrient load contribution from septage in holding tanks will be determined using the nutrient concentrations in septage from holding tanks (600 mg TN/L and 250 mg TP/L), as reported in Wastewater Engineering, Third Edition (Metcalf and Eddy, 1991). The nutrients removed per holding tank pump-out are shown in Table 5, calculated using the above concentrations.

**Table 5. Nutrient Reductions from a Holding Tank Pump-Out**

| | Total N (lbs/tank/pump-out) | Total P (lbs/tank/pump-out ) |
|---|---|---|
| **Holding Tank Effluent** | 1.03 | 0.32 |
| **Holding Tank Septage** | 1.68 | 0.70 |
| **Total** | 2.71 | 1.02 |

***<u>Effluent:</u>***
*Nutrients Removed (lbs/tank/pump-out) =*
*Conc. (mglL) x (lb/453,592 mg) x (2,464 gal/tank) x (3.7854 l/gal)*
***<u>Septage</u>****:*
*Nutrients Removed (lbs/tank/pump-out) =*
*Conc. (mglL) x (lb/453,592 mg) x (336 gal/tank) x (3.7854 l/gal)*

There is 1 holding tank currently in the Appoquinimink Watershed. Each time a holding tank is pumped, 2.71 lbs TN and 1.02 lbs of TP do not enter the Appoquinimink.

Initially, the Department assumed that tanks are pumped-out 16 times per year. The Small Systems Branch, Groundwater Discharges Section of the Division of Water Resources determined this number to be high. Records from the Holding Tank Compliance program indicate that on average, holding tanks are pumped-out about 12 times per year, or once a month (DNREC Groundwater Discharges Section, personal communication, 2001). Thus, this latter figure was used for subsequent calculations to determine the annual load reduction using the equation below.

| | | | | | | |
|---|---|---|---|---|---|---|
| Nutrient load reduction (lbs/yr) | = | Reduction rate (lbs/tank/pump-out) | x | 12 pump-outs / year | x | # of tanks |

EX: TN reduction due to Holding Tank Pump Out:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TN load reduction (lbs/yr) | = | 2.71 lbs TN/tank/pump-out | x | 12 pump-outs / year | x | 1 tank | = | **32.52 lbs TN/yr or 0.09 lbs TN/day** |

## III. <u>OWTDS Pump-outs</u>

Using a GIS, an analysis was conducted that determined as of March 2009, there were 1,436 OWTDS in the Appoquinimink Watershed.

Waste haulers usually deliver waste to the nearest wastewater treatment plant. According to information from the Wilmington Treatment Facility, 53 tanks were pumped from the Appoquinimink Watershed in 2001. In addition, it was estimated that 47 tanks from the Appoquinimink Watershed were pumped from the Kent County Treatment Facility in 2001 because they could not give exact information on the number of systems pumped. This equals 100 tanks being pumped out a year in the Appoquinimink Watershed based on a 1,000 gallon tank capacity. By assuming that after three years, a septic tank will contain 750 gallons of effluent and 250 gallons of septage (volumes based on local inspector-hauler observations), and using the concentrations of effluent and septage given above, the effluent load reductions per system achieved by a pump-out program are shown below in Table 6.

**Table 6. Nutrient Reductions from an OWTDS Pump-Out**

| | Total N (lbs/system/pump-out) | Total P (lbs/system/pump-out) |
|---|---|---|
| **OWTDS Effluent** | 0.31 | 0.10 |
| **OWTDS Septage** | 1.25 | 0.52 |
| **Total** | 1.56 | 0.62 |

***Effluent:***
*Nutrients Removed (lbs/system/pump-out) =*
*Conc. (mg/l) x (lb/453,592 mg) x (750 gal/system) x (3.7854 l/gal)*
***Septage:***
*Nutrients Removed (lbs/system/pump-out) =*
*Conc. (mg/l) x (lb/453,592 mg) x (250 gal/system) x (3.7854 l/gal)*

The load reduction in the water column achieved by this practice can be calculated using the following equation.

$$\text{Nutrient load reduction (lbs/yr)} = \text{Reduction rate (lbs/system/pump-out)} \times \left[ \left( \text{\# of existing OWTDS} \times \frac{\text{1 pump-out}}{\text{3 years}} \right) - \text{\# of compliant OWTDS} \right]$$

EX: TN reduction due to OWTDS pump-out program:

$$\text{TN load reduction (lbs/yr)} = \text{1.56 lbs TN/system/pump-out} \times \left[ \left( \text{1,034 existing OWTDS} \times \frac{\text{1 pump-out}}{\text{3 years}} \right) - \text{100 compliant OWTDS} \right]$$

$$= \textbf{381.68 lbs TN/year or 1.05 lbs TN/day}$$

## IV. <u>OWTDS Performance Standards</u>

Wastewater pretreatment technologies exist to remove nitrogen, phosphorus, or both from wastewater prior to soil dispersal of the effluent. A consultant hired by the Department evaluated the performance efficiencies of these technologies then recommended performance standards for OWTDS in Delaware and several levels of performance efficiencies for nitrogen and phosphorus (The On-Site Wastewater Corporation, draft written communication, 2003).

A recommendation in the Appoquinimink Pollution Control Strategy surrounding small septic systems requires new and replacement subdivisions in areas outside of sewer districts to be equipped with systems that can reach standards such as “Performance Standard Nitrogen 3” (PSN3) to reduce nutrients. Technologies that can achieve PSN3 will produce a 50% reduction of effluent TN concentration when compared to the TN influent concentration. The nutrient load reduction can be determined using the following equation.

| Nutrient load reduction (lbs/day) | = | OWTDS loading rate (lbs/system/day) | x | # of existing OWTDS in program | x | Reduction efficiency |
|---|---|---|---|---|---|---|

EX: TN reduction due to upgrading to alternative systems:

| TN load reduction (lbs/day) | = | 0.052 lbs TN/system/ day | x | 1,034 OWTDS | x | 50% | = | **27.1 lbs TN/day** |
|---|---|---|---|---|---|---|---|---|

## Stormwater BMP Calculations

### I. Stormwater BMPs

Several types of structures that treat stormwater runoff are used throughout the Appoquinimink Watershed. The efficiencies associated with common stormwater BMPs are listed in Table 7. In order to calculate the load reduction to the receiving water body, the calculation outlined below is used. The nitrogen urban loading rate is 15 lbs/acre/yr, while the phosphorus loading rate is 0.5 lb/acre/yr (Ritter and Levan, 1992).

**Table 7. Stormwater BMP Reduction Efficiencies (ASCE, 2001)**

| BMP | TN (%) | TP (%) |
|---|---|---|
| **Wet ponds** | 12 | 55 |
| **Dry pond (extended detention)** | 15 | 25 |
| **Infiltration (infiltration basin/trench)** | 65 | 70 |
| **Biofiltration (open channel)*** | 25 | 29 |
| **Filtering Practice (bioretention)** | 38 | 59 |

*Must be at least 200ft long for TN reduction and 100ft swales are more effective in reducing TP (45%) as compared to 200ft swales (29%).

| | | | | | | |
|---|---|---|---|---|---|---|
| Nutrient load reduction (lbs/day) | = | Total drainage area treated by structures (acres) | x | Urban loading rate (lbs/acre/yr) | x | Reduction efficiency |

EX: TN reduction due to wet ponds:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TN load reduction (lbs/day) | = | 5,861.43 acres treated on average | x | 15 lbs TN/acre/yr | x | 12% | = | **10,550.57 lbs TN/yr or 28.91 lbs TN/day** |

### II. Potential Future Stormwater Retrofit Projects:

It is anticipated that an additional 3,156 acres of urban area in the Appoquinimink watershed will be retrofitted in the future. It is difficult to project, however, the exact number and type of treatment structures that will be used. The majority of stormwater practices currently in use in the watershed are wet and dry ponds, while infiltration, biofiltration, and filtration structures together are less likely to be used. It is unlikely that these same proportions will be used in future retrofit projects since the construction of ponds will require a considerable amount of space and it may be unfeasible to create these structures in areas that are already developed. Because of this, it has been assumed that future retrofits will be more equitable with equal implementation of ponds and other practices.

The load reductions achieved from the stormwater BMPs currently on the ground have been summed into two categories, “Ponds” and “Other.” These values were divided by the total area treated in each category to calculate nutrient reduction rates. For “Ponds,” the reduction rates are 1.84 lbs TN/acre/yr and 0.25 lbs TP acre/yr, while the reduction rates for “Other” are 5.69 lbs TN/acre/yr and 0.20 lbs TP acre/yr.

The potential future loading reduction to the stream as a result of retrofitting 3,156 acres of urban lands can thus be determined using the equation below.

| | | | | | | |
|---|---|---|---|---|---|---|
| Nutrient load reduction (lbs/day) | = | Reduction rate (lbs/acre/yr) | x | Acres of retrofit | x | Future percent use of practice |

EX: TN reduction from future stormwater ponds:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TN load reduction (lbs/day) | = | 1.84 lbs TN/acre/yr | x | 3,156 acres | x | 50% | = | **2,904 lbs TN/yr or 7.95 lbs TN/day** |

## Open Space Calculations

### I. Grassed Open Space

Grassed open space is treated as a land use change from agricultural cropland to grassed open space. Thus, the acres that undergo change will receive a lower loading rate. The loading reduction is calculated as follows.

$$\text{Nutrient load reduction (lb/yr)} = \left[\text{Agricultural loading rate (lbs/acre/yr)} - \text{Grass loading rate (lbs/acre/yr)}\right] \times \text{Acres of open space practices}$$

EX: TN reduction due to open space provisions in the UDC:

$$\text{TN load reduction (lb/yr)} = \left[\text{25 lbs TN/acre/yr} - \text{10 lbs TN/acre/yr}\right] \times \text{665 acres} = $$

**9,975 lbs TN/yr or 27.33 lbs TN/day**

### II. Riparian Buffer

It is assumed that for every one acre of land where riparian buffers are employed, that two upland urban acres are treated. This approach is similar to the practice employed by the Chesapeake Bay Program (CBP, 1998). The efficiencies for nutrient load reductions are an average of the range presented by J.T. Sims and J.L. Campagnini (written communication, 2002). Thus, the agreed efficiencies are as follows:

Forested buffers: TN-- 62% and TP-- 62%

For these BMPs, the actual acre of the practice will be treated as a land use conversion and the reduction efficiencies will be applied to two acres of affected upland for each acre of practice.

$$\text{Nutrient load reduction (lb/yr)} = \left[\left[\text{Agricultural loading rate (lbs/acre/yr)} - \text{Forest loading rate (lbs/acre/yr)}\right] \times \text{Acres of buffers}\right] + \left[\text{2 x Acres of buffers} \times \text{Urban loading rate (lbs/acre/yr)} \times \text{Reduction efficiency (\%)}\right]$$

EX: TN reduction due to UDC riparian buffer requirements:

TN load reduction (lb/yr) =

[ ( 25 lbs TN/acre/yr - 5 lbs TN/acre/yr ) x 1,972 Acres ] + [ 2 x 1,972 Acres x 15 lbs TN/acre/yr x 62% ]

**76,119.20 lbs TN/yr or 208.55 lbs TN/day**

# Agriculture BMP Calculations

The following calculations are provided as a result of the Agricultural Pollution Control Strategy Workgroup's efforts in gathering the best available science for nonpoint source pollution prevention from agricultural sources. The workgroup began meeting in April 2002 to gather the best available data on nutrient efficiencies for various agricultural best management practices. These recommendations and calculations are based on averages over several years from different studies and are dependent on weather conditions, soil type, crop production intensity, excess manure generation, topography and other site specific conditions. In addition, a lag time likely exists between practice implementation and benefit observation, which can not currently be estimated since all nutrient fate and transport processes are not well understood at this time.

## I. Cover Crops

Nitrogen reduction efficiencies for cover crops were calculated using a weighted average method for each year. The data used in this calculation came from ranges of cover crop TN efficiencies for several plant species presented by J.T Sims and J.L. Campagnini (written communication, 2002). The Workgroup chose a single efficiency, often an average of the range, for the commonly used species in Delaware (Table 8). The United States Department of Agriculture, National Resource Conservation Service provided information on each cover crop planted in the 2008-2009 season in the Appoquinimink Watershed (shown in bold). This information was used to calculate a weighted average efficiency of the crops planted, determined to be 54.9% for the 2008-2009 season. It should be noted that with this approach, the efficiency will change from year to year, depending on the acreage of each cover crop species planted. For TP, the Workgroup referred to the best professional judgment presented by Sims and Campagnini, which was "less than 5%," and will be considered for these purposes as 4.9%. The nutrient load reduction is calculated with the equation shown below.

**Table 8. Cover Crop Efficiencies for TN**

| Cover Crop Species | Work Group BMP Efficiency (%) |
|---|---|
| Barley | 70 |
| Hairy Vetch | 6 |
| Annual Rye | 65 |
| **Cereal Rye** | **54.5** |
| Oats | 55 |
| **Wheat** | **55** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Nutrient load reduction (lbs/yr) | = | Agricultural loading rate (lbs/acre/yr) | x | Acres of cover crops | x | Reduction efficiency (%) |

EX: TN reduction due to 3,144.80 acres of cover crops:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TN Load Reduction (lbs/day) | = | 25 lbs TN/acre/yr | x | 3,144.80 acres | x | 54.9% | = | **43,162 lbs TN/yr or 118.25 lbs TN/day** |

**II. <u>Ponds, Grassed Waterways, Grassed Filter Strips, Wildlife Habitat</u>**

The Conservation Reserve Program (CRP) practices are treated as a land use change from agricultural cropland to grassed waterways or grassed filter strips, or wildlife habitat. Thus, the acres that undergo change will receive a lower loading rate. Since the Conservation Reserve Enhancement Program (CREP) was implemented, any new grass filter strips created will be treated as a CREP practice and will receive a reduction calculated by the method described later. The loading reduction is calculated as follows.

| | | | | | | |
|---|---|---|---|---|---|---|
| Nutrient load reduction (lb/yr) | = | ( Agricultural loading rate (lbs/acre/yr) | - | Grass loading rate (lbs/acre/yr) ) | x | Acres of CRP practices |

EX: TN reduction due to 1,413.80 acres of wildlife habitat:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TN load reduction (lb/yr) | = | ( 25 lbs TN/acre/yr | - | 10 lbs TN/acre/yr ) | x | 1,413.80 acres | = | **21,207 lbs TN/yr or 58.10 lbs TN/day** |

## III. Filter Strips, Forest Buffers, Riparian Buffers, Wetlands

The Conservation Reserve Enhancement Program (CREP) practices (CP21-grass filter strips) are assumed to act as grassed buffers. CREP practices (CP22-riparian buffer, CP23-wetland restoration and CP3A-hardwood trees) are all assumed to act as forested buffers. The Workgroup assumed that for every one acre of land where these practices are employed, that two upland acres are treated. This approach is similar to the practice employed by the Chesapeake Bay Program (CBP, 1998). The efficiencies for nutrient load reductions are an average of the range presented by J.T. Sims and J.L. Campagnini (written communication, 2002). Thus, the agreed efficiencies are as follows:

Grassed buffers: TN-- 46% and TP-- 54%
Forested buffers: TN-- 62% and TP-- 62%

For these BMPs, the actual acre of the practice will be treated as a land use conversion and the reduction efficiencies will be applied to two acres of affected upland for each acre of practice.

$$\text{Nutrient load reduction (lb/yr)} = \left[\left(\text{Agricultural loading rate (lbs/acre/yr)} - \text{Grass/Forest loading rate (lbs/acre/yr)}\right) \times \text{Acres of CREP practices}\right] + \left[2 \times \text{Acres of CREP practices} \times \text{Agricultural loading rate (lbs/acre/yr)} \times \text{Reduction efficiency (\%)}\right]$$

EX: TN reduction due to 30.8 acres of CREP filter strips:

$$\text{TN load reduction (lb/yr)} = \left[\left(25\ \text{lbs TN/acre/yr} - 10\ \text{lbs TN/acre/yr}\right) \times 30.8\ \text{Acres}\right] + \left[2 \times 30.8\ \text{Acres} \times 25\ \text{lbs TN/acre/yr} \times 46\%\right]$$

$$= \textbf{1170.4 lbs TN/yr or 3.21 lbs TN/day}$$

## IV. Field Border

Nutrient reductions from field borders are treated as Conservation Reserve Program (CRP) practices. These practices are treated as a land use change from agricultural cropland to grassland habitat. Thus, the acres that undergo change will receive a lower loading rate. It is important to note that field borders are measured in feet and must be converted to acres.

$$\text{Nutrient load reduction (lb/yr)} = \left[\text{Agricultural loading rate (lbs/acre/yr)} - \text{Grass loading rate (lbs/acre/yr)}\right] \times \text{Acres of practices}$$

EX: TN reduction due to 18,299 ft of wildlife habitat:

$$\text{TN load reduction (lb/yr)} = \left[25 \text{ lbs TN/acre/yr} - 10 \text{ lbs TN/acre/yr}\right] \times 8.38 \text{ acres} = \mathbf{125.7\ lbs\ TN/yr\ or\ 0.35\ lbs\ TN/day}$$

## V. Critical Area Planting

Critical area planting is a BMP that controls soil erosion and results in phosphorus reductions since phosphorus adsorbs to soils. The critical area planting practice is considered a hot spot BMP and is applied to areas in fields where soils are severely eroding. Soil loss is based upon NRCS values. The critical area planting practice decreases soil erosion from these highly erodible areas from 10 tons per acre per year to 0.5 tons per acre per year, or a soil loss reduction of 9.5 tons per acre per year. To calculate the reduction from this practice, the acreage of the practice is multiplied by the soil loss reduction value, the amount of readily desorbed phosphorus (0.23 mg P/kg soil) (Sims et al. 1994), and conversion factors.

EX: TP reduction due to 35.80 acres of critical area planting:

$$\text{TP load reduction (lb/yr)} = \text{Acres} \times \text{Reduction in soil loss (9.5 tons/ac/yr)} \times \text{Readily desorbed phosphorus (0.23 mg P/kg Soil)} \times \text{Conversion factors}$$

$$\text{TP load reduction (lb/yr)} = 35.8 \text{ Ac} \times \frac{9.5 \text{ tons}}{\text{Ac*yr}} \times \frac{0.23 \text{ mg P}}{\text{kg Soil}} \times \frac{2000 \text{ lbs}}{\text{ton}} \times \frac{\text{kg}}{10^6 \text{ mg}} = \mathbf{0.16\ lb\ TP/yr\ or\ 0.004\ lb\ TP/day}$$

## VI. Conservation Tillage

Conservation tillage is a BMP that controls soil erosion by modifying tillage practices on a farm field which reduces sediment and hence phosphorus losses from the tilled field. Soil loss is again based upon NRCS values. Conservation tillage practice can lower soil erosion to 1.5 tons per acre per year from approximately 4.1 tons per acre per year for conventional tillage, or a soil loss reduction of 2.6 tons per acre per year. To calculate the reduction from this practice, the acreage of the practice is multiplied by the soil loss reduction value, the amount of readily desorbed phosphorus (0.23 mg P/kg soil) (Sims et al. 1994), and conversion factors.

EX: TP reduction due to 4,182.20 acres of conservation tillage:

| TP load reduction (lb/yr) | = | Acres | x | Reduction in soil loss (2.6 tons/ac/yr) | x | Readily desorbed phosphorus (0.23 mg P/kg Soil) | x | Conversion factors |
|---|---|---|---|---|---|---|---|---|

| TP load reduction (lb/yr) | = | 4,182.20<br>Ac | x | 2.6 tons<br>Ac*yr | x | 0.23 mg P<br>kg Soil | x | 2000 lbs<br>ton | x | kg<br>10^6 mg | = | **5 lb TP/yr or 0.01 lb TP/day** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

## VII. Nutrient Management Plans

To reduce agriculture's impact on water quality, Delaware legislated a nutrient management program in 2002 to oversee nutrient applications within the State. In 2003, 20% of farmers applying nutrients to 10 acres or more or those who manage 8 or more animal units within the state were required by the Nutrient Management Act to create and submit a nutrient management plan (NMP) to the Nutrient Management Commission (NMC). Each year between 2004 and 2007, another 20% of eligible farmers were required to have NMPs, with 100% implementation by January 1, 2007. These plans are routinely updated and modified to meet the nutrient needs of the future cropping rotations and practices.

The Delaware Conservation Partnership (DCP) conducted a survey in July 2007, after the deadline requiring all eligible farm operations to have a plan, to evaluate nutrient management planning in the state. The DCP consists of the Delaware Conservation Districts, the Natural Resources Conservation Service, and the Delaware Department of Natural Resources and Environmental Control, and strives to work together to meet the needs of Delaware Farmers by providing cost-share programs, educational opportunities, and nutrient management planning services. The survey was designed to inform those programs by identifying gaps in information and education and opportunities to spend cost-share dollars more effectively. In short, the purpose of the project was to make nutrient management work better for farmers in Delaware.

The surveys were sent out to everyone who has been certified by the Nutrient Management Program- 2,034 people in all. The Delaware Conservation Partnership received 698 responses- about a 34% response rate. The following is the breakdown of responses among different sizes of farms:

1-10 acre farms – 9% response rate
11-99 acre farms – 29% response rate
100-499 acre farms – 25% response rate
500 + acre farms – 20% response rate
Animal only farms – 10% response rate

Responses varied only slightly among different farm sizes and types, with the exception of whether or not nutrient management provided an economic benefit to their farm. Larger farms and those whose plans were written by a private consultant were most likely to agree that nutrient management provides an economic benefit to their operation. Small farms, animal operations and those whose plan was written by someone on staff were least likely to agree.

The surveys indicated that fertilizer application rates have decreased the most among farmers who till at least 500 acres, while manure applications have decreased most among farmers who till between 11 and 99 acres. When fertilizer application rates are evaluated by county, Sussex farmers reduced the rate of N and P applications the most, Kent reduced N applications the least, whereas New Castle deceased P applications the least.

Table 5. Change in Fertilizer and Manure Application Rates Due to 2002 Nutrient Management Law

| *County* | *Farm Acres* | *% Change in nitrogen fertilizer applications* | *% Change in phosphorus fertilizer applications* | *% Change in manure application* |
|---|---|---|---|---|
| Kent | 173,808 | 13.4 | 26.9 | 5.4 |
| New Castle | 66,981 | 16.0 | 20.1 | 13.6 |
| Sussex | 269,464 | 18.5 | 37.1 | 24.2 |
| Weighted Average | | 16.7 | 1.4 | 19.9 |

The efficiencies based on the DCP survey can be compared to other estimates of nutrient management planning effectiveness. An Agricultural Workgroup was established to gather the best available science on nonpoint source pollution prevention for agricultural sources. The Workgroup operated off the basic assumption that if fewer nutrients are being applied to the land, fewer nutrients will be lost to Delaware's water bodies. From this premise, the Workgroup determined nutrient efficiencies for various agricultural best management practices including the effectiveness of nutrient management planning.

Initially, the Workgroup addressed the impact of nutrient management planning (NMP) in the Inland Bays and Nanticoke watersheds from a study by McGowan and Milliken (1992). This study listed the reductions associated with various management practices observed over a three year period, with a total of 103,736 lbs TN reduced by 2,328 acres under nutrient management planning. To determine a general NMP TN reduction, the Workgroup decided that the reductions and acreage associated with manure allowance and cover crops should be removed from further calculations since reductions for both of these items are determined separately and all NMPs will not include manure relocation. This subtraction gave a total of 1,224 acres of nutrient management planning and a load reduction of 70,136 lbs of TN, resulting in a reduction rate of 57.3 lbs/acre per 3-year planning cycle. McGowan and Milliken (1992) reported that the TN application rate prior to the introduction of NMPs was 280 lbs/acre per 3-year planning cycle, so NMPs produced a 20.5% reduction in TN. This estimate falls in the lower range reported by the State of Maryland (MDNR, 1996), which was 20-39% for nitrogen. The corresponding phosphorus range reported by the Maryland DNR was 9-30%. However, due to the absence of a report similar to the McGowan and Milliken study in Delaware for P, there is not enough information available to determine an appropriate reduction efficiency to apply to NMPs for phosphorus in these two watersheds.

In the Appoquinimink watershed, one representative farm within the watershed volunteered to allow the Workgroup to analyze the nutrient data they routinely gather. This particular farm tracks nutrient application rates to each crop field within a database that goes back to 1999, prior to the passing of the Nutrient Management Act. The data were separated into two groups, pre-Nutrient Management Plans (NMPs) (1999-2002) and post-NMPs (2003-2004), and entered into Statgraphics Software for statistical analysis. It was determined that there was a statistically significant difference between the mean application rates at the 95% confidence level for nitrogen. The average nitrogen application rate decreased by 12.4% from the pre-NMP level and this value will be taken as the NMP reduction efficiency; unfortunately, no reduction could be calculated for phosphorus from this data.

At the request of the NMC, Sims et al. (2008) conducted extensive nutrient mass balance calculations for the State for the years 1996 through 2006. They calculated both input/output and management–oriented mass balances for nitrogen and phosphorus. The Sims et al. (2008) approach included calculations for manure relocation and estimates of biological fixation of nitrogen by leguminous crop and clearly demonstrated that fewer nutrients are being applied to Delaware’s cropland.

DNREC Watershed Assessment Section (WAS) has worked with the NMC and the University of Delaware Cooperative Extension to determine the impact of the Nutrient Management Act on the amount of nutrients applied to Delaware’s agricultural fields. Using an input-output type analysis using fertilizer sales data and crop yields, WAS determined that on a state-wide basis, 47% less nitrogen and 62% less phosphorus has been applied to Delaware's cropland.  Both the WAS and Sims et al. (2008) approach produced similar results.

The DCP values, which are based on the reductions in nutrient applications actually reported by Delaware farmers, fall within the range of efficiencies determined by the numerous other methods and data sets discussed above.  As a result, DNREC proposes to use the DCP efficiencies to estimate the reduction in nutrient application rates resulting from the promulgation of the Nutrient Management Law.

There were 12,583.65 acres of nutrient management planning in the Appoquinimink Watershed in 2008.  Using the TN and TP efficiencies and the agricultural loading rate reported earlier, the annual and daily load reductions due to these acres can be calculated as follows.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TN load reduction (lb/yr) | = | 12,583.65 acres under NMPs | x | Agriculture loading rate (25 lbs TN/acre/yr) | x | Reduction efficiency (16%) | = | **50,333.5 lbs TN/yr or 137.9 lbs TN/day** |

## Overall Nutrient Load Reductions

The total nutrient reductions achieved by practices currently on the ground in the wastewater, stormwater, open space and agricultural sectors have been determined. In addition, the nutrient reductions possible from several potential future wastewater management policies and stormwater projects have also been estimated. These values are shown in Table 10 along with the nutrient reductions required to meet the TMDL goals. Current practices have contributed 109% percent of the required TN reduction and 111% percent of the required TP reduction. Potential reductions from the wastewater and stormwater sectors increase the progress for TN to 118% and 126% for TP.

| Table 10. Nutrient Reductions Achieved from Current and Potential Future BMPs | | |
|---|---|---|
| | **TN Reduced (lbs/day)** | **TP Reduced (lbs/day)** |
| **Wastewater** | 1.04 | 0.24 |
| **Stormwater** | 39.47 | 7.11 |
| **Agriculture** | 673.49 | 12.88 |
| **Open Space** | 260.19 | 5.76 |
| **Sub-total** | **974.19** | **25.99** |
| **Future Wastewater** | 47.08 | 1.77 |
| **Future Stormwater** | 32.57 | 1.96 |
| **Total** | **1,053.83** | **29.72** |
| **Required Reduction** | **890.83** | **23.50** |

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# APPENDIX E

# BMP COST CALCULATIONS

This document describes the cost-effectiveness of urban and agricultural best management practices (BMPs) that reduce nutrients.

## On-Site Wastewater Treatment and Disposal System (OWTDS) BMP Cost Calculations

### I. Connecting OWTDS to Sewer Districts

According to DNREC's Financial Assistance Branch (personal communication, 2007), the average cost of constructing a sewer system is $8,500 per equivalent dwelling unit (EDU). In the future, this cost is expected to increase to $10,000/EDU. The debt service, or cost of financing these systems, at roughly an average 2% rate is currently $1,867/EDU and will be $2,194/EDU for future septic eliminations and sewer connections. Additionally, system owners must pay for the final septic system pump-out, crushing and filling the tank, and the connection costs associated with building the lateral line running from the building to the right of way. These three expenditures together run approximately $1,000/EDU. Finally, operation and maintenance (O&M), including repair fees, of roughly $200 per EDU per year will also be added to these values for an average 20 year lifespan of a connection (DNREC Financial Assistance Branch, personal communication, 2007) (Table 1).

**Table 1. OWTDS Elimination Costs**

| | Past Conversions | Future Conversions |
|---|---|---|
| **Construction of sewer system** | $8,500/EDU | $10,000/EDU |
| **Debt service** | $1,867/EDU | $2,194/EDU |
| **Additional expenditures** | $1,000/EDU | $1,000/EDU |
| **Operation and Maintenance (over 20 year lifespan)** | $4,000/EDU | $4,000/EDU |
| **TOTAL** | $15,367/EDU | $17,194/EDU |

### II. Holding Tank Inspection and Compliance Program

The cost of pumping-out a 2,800 gallon holding tank averages around $250 per system per pump-out (DNREC Small Systems Branch, personal communication, 2007). As a result of the holding tank inspection and compliance program, they have been shown to be pumped-out roughly 12 times a year. This information reveals that the owner of a single holding tank will spend $3,000 each year. In addition to this cost, there is an annual inspection fee of $60 per system (DNREC Small Systems Branch, personal communication, 2007), so that the total expenditure for holding tank inspection and compliance is $3,060/system/year and over a 20 year lifespan the cost is $61,200/system.

## III. OWTDS Pump-outs

The cost of pumping-out OWTDS ranges from $185-200 per system, with an average cost of $192.50 per system (DNREC Small Systems Branch, personal communication, 2007). It is proposed that septic systems be pumped once every three years and inspected during that time period as well. These proposed inspections will be performed by licensed inspectors at an estimated cost that ranges from $200 to $400 with an average cost of $300 at the time of pump-out (DNREC Small Systems Branch, personal communication, 2007). The total cost of the OWTDS inspection and compliance program will cost the system owner $164.17/system/year and over a 20 year lifespan this equals $3,283.33/system.

## IV. OWTDS Performance Standards

Licensed installers and members of DNREC's Small Systems Branch (personal communication, 2007) revealed that the installation of best available technologies (BATs) to existing small (<2,500 gallon per day (gpd)) OWTDSs for advanced nitrogen removal would cost between $3,500 and $6,000 per system with an average installation of $4,750. These technologies are believed to last for approximately 20 years. These technologies require a service contract by a certified service provider with an estimated annual cost that ranges from $150 to $300, with an average cost of $225/system/year. In addition, the systems will still require pump-outs, which costs $64/system/year (DNREC Small Systems Branch, personal communication, 2007), and they will need periodic mechanical parts repaired, estimated to cost $50/system/year and the electrical cost of running the systems is likely to also cost about $50/system/year (DNREC Financial Assistance Branch, personal communication, 2007). Taking all of this into account, the total cost of this strategy is $12,530/system.

## Stormwater BMP Cost Calculations

### I. Wet and Dry Ponds

Typical costs for retention basins were retrieved from Chapter 6.0, “Costs and Benefits of Storm Water BMPs,” of an EPA on-line document (EPA, 1999). In this document, it states that a retention basin treating a 50-acre residential site in 1999 costs about $100,000, such that the cost per unit area was $2,000/acre. All values reported in the document need to be divided by an adjustment factor to account for regional differences. Delaware falls in Region 2, which has a 0.90 adjustment factor (EPA, 1999). Thus, retention basins in Delaware in 1999 cost approximately $2,222.22/acre. Using the average annual federal inflation rate for the time period of 1913-2007 (3.42%), the capital cost of Delaware retention basins in 2009 is $2,982/acre. To this value, the annual operation and maintenance costs over a 25 year lifespan must be added. Operation and maintenance costs for retention basins were determined from New Castle County Department of Land Use’s guidance found in the document “Maintenance (Minor) and Replacement (Major) Costs for Stormwater Management Facilities Preliminary Guidance Version #6” (NCC, 2005). Maintenance costs for wet and dry ponds include the following:

**Table 2. Retention Pond Maintenance Costs**

| | Frequency | Unit Cost for Wet Ponds | Unit Cost for Dry Ponds | Annual Cost for Wet Ponds (40 acres) | Annual Cost for Dry Ponds (20 acres) |
|---|---|---|---|---|---|
| **Inspection** | 2 times a year | $800 per inspection | $800 per inspection | $1,600 | $1,600 |
| **Sediment Removal with Forebay** | 1 time over 10 years | Based on removal of 0.5 ft of 2,000 sq ft forebay | Based on removal of 0.5 ft of 1,000 sq ft forebay | $2,200 | $1,120 |
| **Erosion Repair** | 1 time over 2 years | $4,400 | $4,400 | $2,200 | $2,200 |
| **Repair Low Spots in Berm** | 1 time over 5 years | Based on 20 cy of repair | Based on 10 cy of repair | $1,280 | $640 |
| **Repair Barrel Leaks** | 1 time over 5 years | $1,250 per event | $1,250 per event | $250 | $250 |
| **Mowing** | 10 times a year | Based on 2 acres mowed @ $300/acre | Based on 2 acres mowed @ $300/acre | $6,000 | $6,000 |

| | | | | | |
|---|---|---|---|---|---|
| **Repair Animal Burrows** | 1 time a year | $200 | $200 | $200 | $200 |
| **Spray for Cattails and Algae (Wet Ponds)** | 2 times a year | $465 | | $930 | |
| **Invasive Removal (Wet Ponds)** | 1 time a year | $3,000 | | $3,000 | |
| **Total Annual Cost** | | | | $17,660.00 | $12,010.00 |
| **Total Cost per Acre** | | | | **$441.50** | **$600.50** |

Including all maintenance costs and dividing by the total acres assumed, the annual cost per acre for wet ponds is $441.50/acre/yr and for dry ponds is $600.50. Adding this to the regionally adjusted construction cost over the 25 year lifespan, the total cost for this strategy is $14,019.50/acre for wet ponds and $17,994.50/acre for dry ponds.

## II. Infiltration Structures

The 1999 construction costs of infiltration trenches and infiltration basins treating 5-acre commercial sites were averaged to represent the range of infiltration structures utilized as stormwater BMPs throughout Delaware. These costs were $45,000 for trenches and $15,000 for basins (EPA, 1999), which equates to $9,000/acre and $3,000/acre, respectively, and averages $6,000/acre. Once adjusted for the regional variability in cost (0.90 factor), and inflated to 2009, this value becomes $8,946.67/acre treated by infiltration structures. Annual O&M costs for infiltration structures were determined from New Castle County estimates (NCC, 2005) as follows:

**Table 3. Maintenance Costs for Infiltration Structures**

| | Frequency | Unit Cost for Infiltration Basin | Unit Cost for Infiltration Trench | Annual Cost for Infiltration Basin (20 acres) | Annual Cost for Infiltration Trench (1 acre) |
|---|---|---|---|---|---|
| **Inspection** | 2 times a year | $800 per inspection | $200 per inspection | $1,600 | $400 |
| **Sediment Removal** | 1 time over 10 yrs with forebay (basin) / 1 time over 2 yrs (trench) | Based on removal of 0.5 ft of 1,000 sq ft forebay | $350 per event | $1,120 | $175 |

| | | | | | |
|---|---|---|---|---|---|
| **Erosion Repair** | 1 time over 2 years/ 1 time over 3 years (trench) | $4,400 | $1,200 | $2,200 | $400 |
| **Repair Low Spots in Berm** | 1 time over 5 years | Based on 10 cy of repair | | $640 | |
| **Repair Barrel Leaks** | 1 time over 5 years | $1,250 per event | | $250 | |
| **Mowing** | 10 times a year | Based on 2 acres mowed @ $300/acre | Based on 200 sq ft mowed @ $300/acre | $6,000 | $110 |
| **Repair Animal Burrows** | 1 time a year | $200 | | $200 | |
| **Total Annual Cost** | | | | $12,010.00 | $1,085.00 |
| **Total Cost per Acre** | | | | **$600.50** | **$1,085.00** |

This produces an annual O&M cost of $600.50/acre/yr for infiltration basins and $1,085.00/acre/yr for infiltration trenches. This averages out to $842.75 which when calculated over a 25 year lifespan and added to construction costs equals $30,015.42/acre.

## III. <u>Filtering Practices</u>

The EPA on-line document reported that the construction costs for filtering practices in 1999 were $35,000 - $70,000, $60,000 for bioretention facilities, and $9,000 for filter strips for a 5-acre commercial site (EPA, 1999), which when averaged equates to $8,700/acre. Once adjusted for the regional variability in cost (0.90 factor), and inflated to 2009, this value becomes $13,083.31. The O&M costs reported by New Castle County for filtering practices (NCC, 2005) are as follows:

| Table 4. Filtering Practices Maintenance Costs | | | | | |
|---|---|---|---|---|---|
| | **Frequency** | **Unit Cost for Bioretention** | **Unit Cost for Filter Strips** | **Annual Cost for Bioretention (1 acre)** | **Annual Cost for Filter Strips (1 acre)** |
| **Inspection** | 2 times a year | $200 per inspection | $200 per inspection | $400 | $400 |
| **Sediment Removal** | 1 time over 2 years/ 1 time over 3 years (filter strips) | $350 per event | $350 per event | $175 | $117 |
| **Erosion Repair** | 1 time over 3 years | $1,200 | $1,200 | $400 | $400 |
| **Mowing** | 8 times a year | | Based on 2000 sq ft mowed @ $300/acre | | $110 |
| **Soil Amendments** | 1 time a year | $100 | $100 | $100 | $100 |
| **Plant Maintenance** | 1 time a year | $400 | | $400 | |
| **Total Annual Cost** | | | | $1,475.00 | $1,127.00 |
| **Total Cost per Acre** | | | | **$1,475.00** | **$1,127.00** |

The maintenance costs for bioretention facilities are $1,475.00/acre and the maintenance costs for filter strips are $1,127.00/acre. The average maintenance costs of these filtering practices are $1,301.00/acre. Calculating the O&M costs over a 25 year lifespan and adding to construction costs provides a total cost of $45,608.31/acre.

## IV. <u>Biofiltration</u>

The EPA on-line document reported that the construction costs for biofiltration devices in 1999 were $3,500 for a 5-acre commercial site (EPA, 1999), which equates to $700/acre. This value must also be divided by the 0.90 adjustment factor to account for regional cost differences, which yields $777.78/acre, and then adjusted to the 2009 value, $1,052.68/acre. The annual maintenance costs for bioswales according to New Castle County (NCC, 2005) are as follows:

| Table 5. Biofiltration Maintenance Costs | | | |
|---|---|---|---|
| | **Frequency** | **Unit Cost for Biofiltration** | **Annual Cost for Biofiltration (10 acres)** |
| **Inspection** | 2 times a year | $200 per inspection | $400 |
| **Sediment Removal** | 1 time over 3 years | $350 per event | $117 |
| **Erosion Repair** | 1 time over 3 years | $1,200 | $400 |
| **Mowing** | 10 times a year | Based on 8000 sq ft mowed @ $300/acre | $440 |
| **Soil Amendments** | 1 time a year | $100 | $100 |
| **Total Annual Cost** | | | $1,457.00 |
| **Total Cost per Acre** | | | **$145.70** |

The maintenance costs for biofiltration facilities are $145.70/acre. Calculating the O&M costs over a 25 year lifespan and adding to construction costs provides a total cost of $4,695.18/acre.

| Table 6. Stormwater BMP Costs | | | | | |
|---|---|---|---|---|---|
| | **Dry Ponds** | **Wet Ponds** | **Infiltration Structures** | **Filtering Practices** | **Biofiltration** |
| **Construction Cost /acre** | $2,982.00 | $2,982.00 | $8,946.67 | $13,083.31 | $1,052.68 |
| **Maintenance Cost /acre** | $600.50 | $441.50 | $842.75 | $1,301.00 | $145.70 |
| **Annual Maintenance/ acre over a 25 year lifespan** | $15,012.50 | $11,037.50 | $21,068.75 | $32,505.00 | $3,642.50 |
| **Total Cost/acre** | **$17,994.50** | **$14,019.50** | **$30,015.42** | **$45,608.31** | **$4,695.18** |

## Open Space Cost Calculations

The costs of the following open space practices have been estimated using data gathered by DNREC's Division of Fish and Wildlife staff. These are estimates, as costs for specific projects may vary.

**I. Grassed Open Space**

For municipalities and counties to restrict development in grassed open space as part of their development process, it is estimated that it costs $400/acre (personal communication, 2009). With a lifespan of 25 years and average maintenance costs of $35.00/acre/year, the total cost of implementation is $1,275/acre.

**II. Riparian Buffers**

For municipalities and counties to restrict development in riparian buffer areas as part of their development process, it is estimated that it costs $450/acre (personal communication, 2009). With a lifespan of 25 years and average maintenance costs of $84.00 /acre/year, the total cost of implementation is $2,550/acre.

## Agriculture BMP Cost Calculations

The costs of the following agricultural BMPs have been estimated using data gathered by the United States Department of Agriculture (USDA) Natural Resources & Conservation Service (NRCS) staff at the county and state level. These are estimates, as costs for specific projects may vary.

### I. Cover Crops

NRCS staff report that the cost of installing cover crops is $49.33/acre. With a lifespan of a year and maintenance costs of $5/acre/year, it costs a total of $54.33/acre to implement. The USDA-NRCS has a cost share program through EQIP for cover crops that covers $37/acre whereas the New Castle Conservation District (NCCD) runs the state cost share program with funding of $50/acre.

### II. Ponds

Ponds have an installation cost of $3,758.50/acre and a lifespan of 10 years with maintenance costs of $5/acre/year. This provides a total cost of $3,808.50/acre to implement. Cost sharing levels of capital costs include 50% of the costs with a maximum of $4,500 from the NCCD.

### III. Grassed Waterways

Grassed waterways cost approximately $16,404.24/acre to install. With a lifespan of 10 years and maintenance costs of $5/acre/year, it costs a total of $16,454.24/acre. Capital costs are cost shared by the USDA-NRCS through the CRP at 50% the cost and EQIP program at $12,303.18/acre while the New Castle Conservation District cost shares at 75%.

### IV. Grass Filter Strips/Wildlife Habitat

These practices are estimated to cost $495.24/acre for installation. This practice has a lifespan of 10 years with maintenance costs of $5/acre/year. Thus, total costs equal $545.24/acre. The installation of these BMPs are cost shared by the USDA-NRCS through the CRP and CREP programs at 50% and through the EQIP and WHIP program at a rate of $371.43/acre. The New Castle Conservation District cost shares these practices at a rate of 75% for EQIP practices and 37.5% for CREP practices.

### V. Forested Buffers/Riparian Buffers

The cost of installing a forested buffer is $495.24/acre with a lifespan of 10 years and maintenance equaling $5/acre/year. The cost installing a riparian buffer is $502/acre with a lifespan of 10 years and maintenance equaling $5/acre/year. The total cost of forested buffers equals $535.24/acre and the total cost of riparian buffers equals $552/acre. The installation of forested buffers are cost shared by the USDA-NRCS through the CREP program at 50% and through the WHIP program at a rate of $371.43/acre. The New Castle Conservation District cost shares forested buffers at a rate of 75% for WHIP practices and 37.5% for CREP practices. The installation of riparian buffers are cost shared by the USDA-NRCS through the CREP and CRP programs at 50% and through the WHIP program at a rate of $376.50/acre. The New Castle Conservation District cost shares riparian buffers at a rate of 75% for WHIP practices and 37.5% for CREP practices.

## VI. **<u>Wetland Restoration</u>**

Wetland restoration costs $4,374.50/acre. This practice has a lifespan of 10 years and maintenance equaling $5/acre/year. Thus, the total cost of the wetland restoration equals $4,424.50/acre. The installation of wetlands are cost shared by the USDA-NRCS through the CRP and CREP programs at 50% and through the WHIP program at a rate of $3,280.88/acre. The New Castle Conservation District cost shares wetlands at a rate of 75% for WHIP practices and 37.5% for CREP practices.

## VII. **<u>Field Border</u>**

Field borders cost $495.24/acre with a lifespan of 10 years and maintenance of $5/acre/year. This equals a total cost of implementation of $545.24/acre. The USDA-NRCS cost shares field borders through the EQIP and WHIP programs at a cost share rate of $215.18/acre and the New Castle Conservation District at a rate of 75%.

## VIII. **<u>Critical Area Planting</u>**

The cost of installing critical area plantings equals $7,229.24/acre. When maintenance of $5/acre/year is added over a 10 year lifespan, the total cost of this practice is $7,279.24/acre. The USDA-NRCS cost shares field borders through the EQIP program at a cost share rate of $5,421.93/acre and the New Castle Conservation District at a rate of 75%.

## IX. **<u>Conservation Tillage</u>**

Implementing conservation tillage costs $17.33/acre and has a lifespan of 4 years with $5/acre/year of maintenance. This equals a total cost of $37.33/acre. The USDA-NRCS cost shares conservation tillage at a rate of $13/acre.

## X. **<u>Nutrient Management Plans (NMPs)</u>**

The cost to develop a nutrient management plan decreases as the acreage in the plan increases. A three year plan for an operation with less than 500 acres costs $5.70 which is the size of the majority of farms in the Appoquinimink watershed.

| Table 3. Agriculture BMP Costs | | | | |
|---|---|---|---|---|
| | **Installation Cost / Acre** | **Lifespan (years)** | **Total Maintenance Costs over Lifespan** | **Total Costs/ Acre** |
| **Cover Crops** | $49.33 | 1 | $5 | $54.33 |
| **Ponds** | $3,758.50 | 10 | $5 | $3,808.50 |
| **Grassed Waterways** | $16,404.24 | 10 | $5 | $16,454.24 |
| **Filter Strips/Wildlife Habitat** | $495.24 | 10 | $5 | $545.24 |
| **Forest Buffers** | $495.24 | 10 | $5 | $545.24 |
| **Riparian Buffers** | $502.00 | 10 | $5 | $552.00 |
| **Wetland Restoration** | $4,374.50 | 10 | $5 | $4,424.50 |
| **Field Border** | $495.24 | 10 | $5 | $545.24 |
| **Critical Area Planting** | $7,229.24 | 10 | $5 | $7,279.24 |
| **Conservation Tillage** | $17.33 | 4 | $5 | $37.33 |
| **NMP** | $5.70 | 1 | - | $5.70 |

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