Best Management Practices for Delaware Golf Courses

March 2019

FOREWORD

Delaware's golf course superintendents are dedicated to protecting the state's natural resources. As a demonstration of this commitment, superintendents have partnered with University of Delaware scientists to develop and document best management practices (BMPs) for golf course management. BMPs help golf course superintendents protect our state's surface and groundwater resources, provide habitat for wildlife, reduce pesticide usage, and conserve energy.

We have developed these research-based, voluntary guidelines specifically for our state. By documenting and implementing these practices across the state, we hope to showcase our role as environmental stewards and inform stakeholders about our commitment to this role.

- *Delaware BMP Steering Committee Members*

ACKNOWLEDGEMENTS

The development of the *Best Management Practices for Delaware Golf Courses* was made possible by superintendents in the state of Delaware, the Eastern Shore Association of Golf Course Superintendents, and scientists from the University of Delaware.

The following golf course superintendents led the effort as members of the Delaware BMP Steering Committee:

- William Reil, Gibson Island Club and Corporation
- John Jacob, Deerfield Golf and Country Club
- Greg Thomas, The Rookery Golf Club
- Jamie Palokas, Baywood Greens
- Jonathan Urbanski, Wilmington Country Club

The following scientists from the University of Delaware provided their input in developing the BMPs and reviewing drafts:

- Erik Ervin, Professor, Turfgrass and Horticultural Systems
- Bruce Vasilas, Professor, Agronomy and Soil Science
- Sue Barton, Professor, Ornamental Horticulture
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- Amy Shober, Professor, Soils and Nutrient Management
- Nancy Gregory, Director, Plant Diagnostic Clinic
- Deborah Delaney, Associate Professor, Entomology
- John Kaszan, M.S. student, Plant and Soil Science
- Kerry Richards, Pesticide Safety Education Program

University of Delaware | Cooperative Extension
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Representatives from these organizations provided their time and expertise to develop best management practices specifically for Delaware to protect the state's natural resources. The Delaware Department of Natural Resources and Environmental Control and the Delaware Department of Agriculture reviewed the draft final version of this document and contributed time and expertise to provide comments to the steering committee. The final result is realistic and implementable guidance for the state's golf turf industry.

Funding and support for this project provided by the Golf Course Superintendents Association of America (GCSAA) and the Eastern Shore Association of Golf Course Superintendents. The Environmental Institute for Golf (EIFG) and the United States Golf Association (USGA) funded GCSAA to develop the Best Management Practices template that served as source material for this project.

Eastern Shore Chapter GCSAA Golf Course Superintendents Association of America

Golf Course Superintendents Association of America

GCSAA is the professional association for the men and women who manage and maintain the game's most valuable resource: the golf course. Today, GCSAA and its members are recognized by the golf industry as one of the key contributors in elevating the game and business to its current state.

Since 1926, GCSAA has been the top professional association for the men and women who manage golf courses in the United States and worldwide. From its headquarters in Lawrence, Kansas, the association provides education, information, and representation to more than 17,000 members in more than 72 countries. GCSAA's mission is to serve its members, advance their profession, and enhance the enjoyment, growth, and vitality of the game of golf.

Environmental Institute for Golf

EIFG fosters sustainability by providing funding for research grants, education programs, scholarships, and awareness of golf's environmental efforts. Founded in 1955 as the GCSAA Scholarship & Research Fund for the Golf Course Superintendents Association of America, the EIFG serves as the association's philanthropic organization. The EIFG relies on the support of many individuals and organizations to fund programs to advance stewardship on golf courses in the areas of research, scholarships, education, and advocacy. The results from these activities, conducted by GCSAA, are used to position golf courses as properly managed landscapes that contribute to the greater good of their communities. Supporters of the EIFG know they are fostering programs and initiatives that will benefit the game and its environment for years to come.

United States Golf Association

USGA provides governance for the game of golf, conducts the U.S. Open, U.S. Women's Open, U.S. Senior Open, 10 national amateur championships, two state team championships, and international matches, and celebrates the history of the game of golf. The USGA establishes equipment standards, administers the Rules of Golf and Rules of Amateur Status, maintains the USGA Handicap System and Course Rating System, and is one of the world's foremost authorities on research, development, and support of sustainable golf course management practices.

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Acronyms

ABW	annual bluegrass weevil
ACRC	Ag Container Recycling Council
AST	above-ground storage tank
B	boron
BMP	best management practice
Ca	calcium
CCE	calcium carbonate equivalence
CEC	cation exchange capacity
CEU	continuing education credit
Cu	copper
CWA	Clean Water Act
DDA	Delaware Department of Agriculture
DNREC	Department of Natural Resources and Environmental Control
DO	dissolved oxygen
DU	distribution uniformity
EEIF	Energy Efficiency Investment Fund
EPA	Environmental Protection Agency
ET	evapotranspiration
Fe	iron
FEMA	Federal Emergency Management Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FIV	fertility index value
FRAC	Fungicide Resistance Action Committee
GCSAA	Golf Course Superintendents Association of America
HOC	height of cut
HRAC	Herbicide Resistance Action Committee
HVAC	heating, ventilation, and air conditioning
IBDU	isobutylidene diurea
IPM	integrated pest management
IRAC	Insecticide Resistance Action Committee
K	potassium
Lb/A	pounds per acre
LEED	Leadership in Energy and Environmental Design
Mg	magnesium
mg/L	milligrams per liter
Mg	magnesium
Mn	manganese
N	nitrogen
NOI	notice of intent
NO3-N	nitrate
NPA	Nebraska Pesticide Act
NPDES	National Pollution Discharge Elimination System
NRC	Nebraska Natural Resources Commission
NRD	Natural Resource District
NTEP	National Turfgrass Evaluation Program
OSHA	Occupational Safety and Health Administration
P	phosphorus
PAW	plant available water
PGR	plant growth regulator
PPE	personal protective equipment
ppm	parts per million
S	sulfur
SCU	sulfur coated urea
SDS	Safety Data Sheet
SGN	size guide number
SWAPP	Source Water Assessment and Protection Program
SWPPP	Stormwater Pollution Prevention Plan
TDS	total dissolved solids
TMDL	Total Maximum Daily Load
S	sulfur
UD-FIV	University of Delaware-fertility index value
UF	ureaformaldehyde
USACE	United States Army Corps of Engineers

USDA	United States Department of Agriculture
USGA	United States Golf Association
UST	underground storage tank
VFD	variable frequency drive
WAP	Water Allocation Permit
WIP	Watershed Implementation Plan
WIN	water-insoluble nitrogen
WIN-PST	Windows Pesticide Screening Tool
WSN	water-soluble nitrogen
Zn	zinc

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1 INTRODUCTION

Delaware's golf course superintendents are dedicated to protecting the state's natural resources. As a demonstration of this commitment, superintendents have partnered with University of Delaware scientists to develop and document best management practices (BMPs) for golf course management. These research-based, voluntary guidelines developed specifically for the state of Delaware, in addition to the state's nutrient and pesticide regulations, not only protect natural resources, they also afford the opportunity for superintendents to be recognized by club members, the public, and state officials as environmental stewards.

Golf courses, especially in urban areas, often represent some of the largest areas of open space around. These large expanses of grass, shrubs, and trees allow water to infiltrate into the ground naturally instead of flowing into storm sewers. This is an example of an ecosystem service that benefits humans and other species directly and indirectly. Other ecosystem services linked to large expanses of turf, like those found on Delaware's golf courses, include temperature moderation, stormwater management, cultural services such as recreation, and supporting services such as nutrient cycling, water cycling, and provisioning of habitat.

1.1 Key Components of Delaware's Golf Course BMPs

BMPs are methods or techniques found to be the most effective and practical means of achieving an objective, such as preventing water quality impacts or reducing pesticide usage. Because of the efforts aimed at protecting water quality, especially in the portions of Delaware located within the Chesapeake Bay watershed, the majority of BMPs in this document relate to water quality. In addition, an emerging concern related to protecting pollinators is also addressed, including identifying specific practices to protect pollinator health as well as expanding habitat for pollinators. Priority topics addressed in this document include the use of nutrients and pesticides, the potential for erosion and sedimentation, water conservation, and emerging concerns related to pollinators. Each area is described briefly below and addressed throughout this document.

1.1.1 Nutrient and Pesticide Usage

The proper use of nutrients and pesticides promotes healthy plant growth which then promotes ecosystem health. When applied properly and in the correct amounts, nutrients are taken up by plants and create a dense, healthy turf that resists diseases and weed encroachment. When properly applied, pesticides are directed to and absorbed or taken up by the target. For example, foliar applied sprays are absorbed by plant leaves, while soil-applied pesticides may be taken up by plant roots. Once in plant tissue, pesticides may be broken down. However, the components of fertilizers (nitrogen and phosphorus) and characteristics of pesticides (toxicity, solubility, and chemical

breakdown rate) can impact water quality and non-target species through off-site movement and exposure.

Best management practices reduce the potential for water quality impacts from fate and transport mechanisms such as runoff, leaching, and drift. For example, nutrient BMPs describe the appropriate amounts of fertilizers that should be applied and when they should be applied to maintain a healthy turf and plants without over-fertilizing. Maintaining vegetated buffer strips along waterways, a key BMP, allows for the deposition of nutrients, pesticides, or sediment in vegetation before reaching a waterway. Pesticide BMPs provide the necessary guidance for the proper transport, storage, mixing, and application of pesticides to address target pests and minimize impacts to non-target species.

1.1.2 Erosion and Sedimentation

Erosion is the action of surface processes that remove soil, rock, or dissolved material from one location and transport it to another. Sedimentation is the deposition of eroded material. Eroded soil and sediments can introduce pollutants into surface waters such as organic matter, nutrients, chemicals (such as pesticides), and other wastes. For example, phosphorus is immobile in most soils and concentrates in the top few inches of the soil, where it is very susceptible to erosion and thus likely to be present in sediment. Design and construction BMPs and stormwater management BMPs address the potential for erosion and sedimentation and ways to mitigate that potential.

1.1.3 Water Usage

Water is a fundamental element for physiological processes in turf such as photosynthesis, transpiration, and cooling, as well as for the diffusion and transport of nutrients. Turf quality and performance depend on an adequate supply of water through either precipitation or supplemental irrigation. Too little water induces drought stress and weakens the plant, while too much causes anaerobic conditions that stunt plant growth and promote disease. Excessive water can also lead to runoff or leaching of nutrients and pesticides into groundwater and surface water. The design and maintenance of irrigation systems, as well as proper irrigation scheduling, careful selection of turfgrass cultivars, and incorporation of cultural practices that increase the water holding capacity of soil are addressed through these BMPs.

1.1.4 Pollinators

Protecting bees and other pollinators is important to the sustainability of agriculture. Minimizing the impacts of pesticides on bees and other pollinators, as well as beneficial arthropods, is addressed in this document in two ways: (1) by promoting the use of integrated pest management (IPM) methods to reduce pesticide usage and minimize the potential of exposure when pesticides are needed and (2) by providing specific guidance for pesticide applicators to follow when chemical control is needed. Superintendents can also directly support healthy pollinator populations by providing and/or enhancing habitat for pollinator species and supplying food sources, nesting sites, and nesting materials.

1.2 Using this Document

This document was developed using the latest science-based information and sources. As of the time of this printing, the information was the latest available; however, the reader should make an effort to identify the latest version. In addition, regulations may change and the reader should make an effort to identify any changes. The accompanying website for this project (www.DelawareGolfBMP.org) is also a resource for identifying these changes.

2 PLANNING, DESIGN, AND CONSTRUCTION

The construction phase of any industry's infrastructure poses the greatest risk of ecosystem alteration. With proper planning and design, golf facilities can be constructed and maintained with minimal impact on water quality and other natural resources. Additional information about incorporating water quality protections into the planning and design phase is found in the "Surface Water Management" and "Maintenance Operations" chapters.

2.1 Regulatory Considerations

Early engagement among developers, designers, local community groups, and permitting agencies is essential to designing and constructing a golf facility that minimizes environmental impact and meets the approval process. Federal, state, and local regulations apply to activities involved in construction activities on golf courses.

2.1.1 Wetlands

During the planning phase, the boundaries of any tidal or non-tidal wetlands or 100-year floodplains on the site must be identified because activities taking place within these boundaries may require permits. On-line mapping tools can be used to view wetlands and more information on Delaware's wetlands can be found on the Delaware Freshwater Wetland Toolbox website.

Delaware wetlands are regulated at both the state and federal levels. At the federal level, wetlands are regulated by the U.S. Army Corps of Engineers (USACE). The USACE is primarily responsible for regulation of non-tidal wetlands in Delaware. At the state level, wetlands are regulated by the Department of Natural Resources & Environmental Control (DNREC).

State regulation is restricted to tidal wetlands or freshwater wetlands of at least 400 acres in area. USACE and DNREC protect such waterbodies from loss and degradation through the regulation of the draining, dredging, and filling of tidal and non-tidal wetlands, of the non-tidal wetland buffer, and of waterways, including the non-tidal 100-year floodplain.

While there are some exemptions from permitting requirements for certain activities, permits or letters of authorization from the state are generally required if a property owner plans to undertake an activity that results in the draining of or the addition of fill materials to a federal or state-regulated wetland or waterway. Delaware wetland regulations and information on permitting, and permit applications are available online. Federal permits can be obtained from the USACE Philadelphia District Regulatory Program.

2.1.2 Floodplains

Any activity associated with construction or renovation, including grading and filling, within the 100-year floodplain zone (non-tidal or tidal) requires a permit issued by the local regulatory

authority (county or town) in keeping with local ordinances. Development in a floodplain is permitted at the local level for incorporated areas and at the county level for all unincorporated areas. DNREC has developed four model floodplain management ordinances, which meet all state and federal regulations and contain recommendations for improved management of floodplains. The DNREC Flood Tool is an interactive web map application designed to provide information about the degree of flood risk for a specific area or property. Map features are connected to geospatial databases that can be queried to obtain pertinent information by which to make informed decisions. If state and federal permits are required, development may not begin until all necessary permits are issued. More information on floodplain permitting is available on the DNREC Drainage and Stormwater webpage.

2.1.3 Erosion and Sediment Control

DNREC has implemented a statewide Sediment and Stormwater Program to control runoff from land disturbing activities in accordance with 7. Del. C. Ch. 40 and 7 DE Admin Code 5101 Sediment and Stormwater Regulations. However, program implementation may be delegated to local agencies, like the conservation districts. Current delegated agencies are listed on the Sediment and Stormwater Program website.

These regulations establish criteria and procedures to enhance erosion and sediment control practices, improve the water quality of construction site runoff, and help maintain surface water quality. The Delaware Erosion & Sediment Control Handbook provides guidance in support of the Sediment and Stormwater Regulations and serves as the official guide for erosion and sediment control principles, methods, and practices. Counties and municipalities may adopt an erosion and sediment control ordinance that meets the intent of Delaware's sediment control laws and regulations.

2.1.4 Listed Species

In addition to the requirement to identify wetlands or floodplains before construction, any federal- or state-listed species or species of concern potentially present on the site should be identified in consultation with the DNREC Division of Fish & Wildlife. Delaware maintains a state endangered species list, a rare plant list, and a Wildlife Action Plan that provides a comprehensive overview of species conservation needs in the state.

2.2 Planning, Design, and Construction Overview

Proper planning minimizes expenses resulting from unforeseen construction requirements. Good planning provides opportunities to maximize/integrate environmentally favorable characteristics into the property. This often requires the involvement of experts in a number of fields.

Proper design meets the needs of the stakeholders, protects the location’s environmental resources, includes site-appropriate drainage features, and is economically sustainable. Design also includes the selection of site-appropriate turf cultivars that ideally require less input to

maintain a healthy and diverse turf. For more information, see the Cultivar Selection section of the "Cultural Practices" chapter of this document. Environmental issues concerning construction need to be addressed during the design phase. Detailed plans, such as the erosion and sediment control plan and the stormwater management plan, will be used by a qualified course builder to construct the facility. Environmentally sound construction methods and management that follow the construction plans and specifications can prevent environmental impacts to the site. For more information, see An Environmental Approach to Golf Course Development. 2008. American Society of Golf Course Architects.

More information on the steps involved in the planning, design and construction phases is provided in Table 1.

2.3 Erosion and Sediment Control

Sediment (loose particles of sand, silt, and clay) and soil can be transported off-site by flowing water and blowing winds. When sediment or eroded soil reaches surface waters, they can degrade water quality by increasing turbidity, harming aquatic plants, and impairing habitat for fish and shellfish. In addition, soil contaminants, such as pesticides, may be transported with eroding soil. These issues are of special concern to the Delaware Inland Bays and their tributaries. Therefore, erosion and sediment control are a critical component of construction and grow-in of a golf course. Regulations and best management practices can be found in the Delaware Erosion & Sediment Control Handbook.

Erosion- and sediment-control regulations require developers, designers, and plan review agencies to consider runoff control from the start of any land development design process. A plan describing how erosion and sediment control will be integrated into the stormwater management strategy must be approved by DNREC. The plan must provide sufficient topographic surveys and soil investigations to identify any limitations that would be imposed on any grading operations. It should also provide a detailed sequence of construction that describes how the grading unit restriction will be met. Adhering to the planning principles should result in development that better fits existing site conditions and reduces both the extent and duration of soil disturbance during construction.

2.4 Wetlands

Wetlands act both as filters for pollutant removal and as nurseries for many species of birds, insects, fish, and other aquatic organisms. When incorporated into golf course design, wetlands should be maintained as preserves and separated from managed turf areas with native vegetation or structural buffers. Constructed or disturbed wetlands may need to be permitted to be an integral part of the stormwater management system as discussed in the Regulatory Considerations section of this chapter and in the "Surface Water Management" chapter.

Table 1. Best practices for golf course planning, design, and construction

Planning	
Step	**Description**
Assemble Team	The team should include, but not be limited to, a golf course architect, golf course superintendent, clubhouse architect, irrigation engineer, environmental engineer, energy analyst, economic consultant, civil engineer, soil scientist, golf course builder, and a legal team.
Define Objectives	Identify realistic goals, formulate a timeline, etc.
Conduct a Feasibility Study	Evaluate finances, environmental issues, water availability and sources, and energy, materials, and labor needs. Identify applicable government regulations.
Select Site	Site should meet project goals and expectations. Identify all strengths and weakness of each potential site. During site selection, any site constraints, such as the presence of listed species or valuable habitat, should be identified.
Design	
Retain a Project Manager/Superintendent	This person is responsible for integrating sustainable practices in the development, maintenance, and operation of the course.
Design the Course	Existing native landscapes should remain intact as much as possible. Should consider adding supplemental native vegetation to enhance existing vegetation alongside lengthy fairways and out-of-play areas. Nuisance, invasive, and exotic plants should be removed and replaced with native species adapted to the area.
	Greens: Should have plenty of sunlight, be well drained, and have plenty of airflow. Greens should be big enough to have several hole locations that can handle expected traffic. Root zone material should be selected with United States Golf Association (USGA) specifications in mind, as published in A Guide to Constructing The USGA Putting Green.
	Grass Selection: Species should be selected based on climate, environmental, and site conditions and species adaptability to those conditions, including disease resistance, drought tolerance, spring green-up, and traffic tolerance.
	Bunkers: The number, size of bunkers depends on considerations, such as the resources available for daily maintenance. For each bunker consider: • The need for drainage. • Entry/exit points and how these will affect wear-and-tear patterns. • The proper color, size, and shape of bunker sands to meet needs. New bunker construction techniques can also be researched to see if they satisfy stakeholders' needs.

Design Irrigation System	Hire a professional irrigation architect, if possible, to design the irrigation system. Keep in mind the different water needs of greens, tees, fairways, roughs, and native areas. Consider the topography, prevalent wind speeds, and wind direction when spacing the heads. Choose the most efficient type of irrigation system considering available resources. The "Irrigation" chapter provides detailed information on irrigation-related BMPs.
Construction	
Select Qualified Contractors	Use only qualified contractors who are experienced in the special requirements of golf course construction. Members of the Golf Course Builders Association of America make great candidates.
Safeguard Environment	Follow all design phase plans and environmental laws. Soil stabilization techniques should be rigorously employed to maximize sediment control and minimize soil erosion. Temporary construction compounds and pathways should be built in a manner that reduces environmental impacts.
Install Irrigation System	Installation should consider the need to move equipment and bury pipe while maintaining the original soil surface grade to minimize the potential for erosion.
Establish Turfgrass	Turfgrass establishment methods and timing should allow for the most efficient progress of work, while optimizing resources and preventing erosion from bare soils before grass is established.

2.5 Drainage

Adequate drainage is necessary for healthy turfgrass. A high-quality BMP plan for drainage addresses runoff containment, adequate buffer zones, and filtration techniques. Drainage of golf course features is only as good as the system's integrity. Damaged, improperly installed, or poorly maintained drainage systems negatively impact play and increases risks to water quality.

2.6 Habitat Considerations

In urban and suburban environments, a golf course may provide the best habitat for many species. A number of golf course management activities can maintain and enhance habitat, and provide food and shelter for numerous species, including mammals, birds, fish, amphibians, reptiles, insects, and native plants (Figure 1). Examples of ways to maintain and enhance habitat include:

- identifying and preserving wildlife and migration corridors to help maintain populations at sustainable levels
- retaining natural buffer areas around wetlands and watercourses to preserve habitat while protecting water quality for aquatic species
- planting native species to provide food for animals and insects
- retaining dead trees to serve as nesting areas
- providing nest boxes for birds, bees, and bats
- removing exotic and invasive species to improve habitat

Figure 1. Natural area around an irrigation pond at Deerfield Golf and Country Club. Photo credit: John Jacob.

The "Pollinator Protection" and "Landscape" chapters provide additional recommendations and BMPs for enhancing habitat on the golf course. The Delaware Invasive Species Council provides lists of invasive species found in Delaware. Delaware's Wildlife Action Plan can also help guide efforts to protect natural habitat areas on your course.

2.7 Turfgrass Establishment

Turfgrass establishment is a unique phase in turfgrass growth, which can require greater quantities of water and nutrients than established turfgrass. To this end, the establishment phase should be considered carefully to minimize environmental risk (Figure 2). Adequate nitrogen and

phosphorus are critical for rapid turf establishment and prevention of soil erosion; therefore, soil testing should be conducted before grow-in to determine the amount of nutrients needed. Long-term problems, such as weed encroachment, diseases, and drought susceptibility can be reduced with proper seedbed fertility. More information can be found in Nutrient Management Guidelines for Commercial Turfgrass Seeding. 2005. University of Maryland.

Figure 2. Care should be taken during turfgrass establishment to minimize erosion potential. Photo Credit: John Jacob.

2.8 External Certification Programs

Golf-centric environmental management programs or environmental management systems, such as Audubon International and the Groundwater Foundation's Groundwater Guardian Green Sites program, can help golf courses protect the environment and preserve the natural heritage of the game (Figure 3). These programs help enhance the natural areas and wildlife habitats that golf courses provide, improve efficiency, and minimize potentially harmful impacts of golf course operations. Golf courses can gain valuable recognition for their environmental education and certification efforts.

Figure 3. Audubon certification is one example of an external program to recognize environmental stewardship efforts on golf courses. Photo Credit: John Jacob.

2.9 Planning, Design, and Construction Best Management Practices

Planning Best Management Practices

- Assemble a qualified team, with all the necessary experts represented.
- Determine objectives and complete a feasibility study (considering finances, environment, water, energy, labor, materials, and governmental regulatory requirements/restrictions).
- Select an appropriate site capable of achieving project goals.
- Identify strengths and weakness of the selected site.
- Identify any rare, protected, endangered, or threatened plant or animal species on the site.

Design Best Management Practices

- Retain a qualified golf course superintendent/project manager at the beginning of the design and construction process to integrate sustainable practices into the development, maintenance, and operation of the course.
- Design the course to retain as much natural vegetation as possible. Where appropriate, consider enhancing existing vegetation through the supplemental planting of native species next to long fairways, out-of-play areas, and water sources.
- Design out-of-play areas to retain or restore existing native vegetation where possible. Nuisance, invasive, and exotic plants should be removed and replaced with native species adapted to that particular site.
- Select a greens location that has adequate sunlight and air movement to meet plant-specific needs and that provides sufficient drainage.
- Choose a green size and sufficient number of hole locations that can accommodate traffic and play damage but are not so large that they are unsustainable.
- Select an appropriate root-zone material for the site.
- Consider the number of bunkers as related to resources available for daily maintenance.
- Select cultivars based on an evaluation of the site and climate conditions.
- Consider bunker entry and exit points. Consider wear patterns and create adequate space for ingress/egress points on greens, tees, fairways, and bunkers.
- Select the proper color, size, and shape of bunker sand to meet needs.
- Define play and non-play maintenance boundaries.

Construction Best Management Practices

- Use a qualified golf course builder, such as a member of the Golf Course Builders Association of America.
- Conduct a pre-construction conference with stakeholders.
- Construction should be scheduled to maximize turfgrass establishment and site drainage.
- Use soil stabilization techniques to minimize soil erosion and maximize sediment containment.
- Maintain a construction progress report and communicate the report to the proper permitting agencies.
- Temporary construction compounds should be sited and built in a way that minimizes environmental impacts.

Erosion and Sediment Control Best Management Practices

- Develop a working knowledge of erosion- and sediment-control management.
- Develop and implement strategies to effectively control sediment, minimize the loss of topsoil, protect water resources, and reduce disruption to wildlife, plant species, and designed environmental resource areas.
- Construct in accordance with the approved Sediment and Stormwater Plan, implementing all prescribed BMPs in accordance with the construction sequence established on the approved Plan.
- Hydro-seeding or hydro-mulching offer soil stabilization.

Wetlands Best Management Practices

- Ensure that proper permitting has been obtained before working on designated tidal or non-tidal wetlands or 100-year floodplains.
- Ensure that wetlands have been properly delineated before working in and around them.

Drainage Best Management Practices

- When constructing drainage systems, pay close attention to engineering details such as subsoil preparation, slopes, backfilling, and the placement of gravel.
- Surface water runoff and internal golf course drains should not drain directly into an open waterbody. Instead, they should discharge through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments.
- The drainage system should be routinely inspected to ensure proper function.

Habitat Considerations Best Management Practices

- Identify the different types of habitat specific to the site.
- Identify the habitat requirements (food, water, cover, space) for identified wildlife species.
- Identify species on the site that are considered threatened or endangered by the state or federal government
- Preserve critical habitat.
- Consult with the DNREC's Division of Fish & Wildlife to identify and preserve regional wildlife and migration corridors.
- Remove nuisance and exotic/invasive plants and replace them with native species that are adapted to a particular site.
- Maintain clearance between the ground and the lowest portion of a fence or wall to allow wildlife to pass, except in areas where animals need to be excluded.
- Retain dead tree snags for nesting and feeding sites, provided they pose no danger to people or property.
- Construct and place birdhouses, bat houses, and nesting sites in out-of-play areas.
- Plant pollinator habitat in out-of-play areas or around the clubhouse and consider participating in Monarchs in the Rough program to provide monarch-specific plantings.
- Retain riparian buffers along waterways to protect water quality and provide food, nesting sites, and cover for wildlife.

Turfgrass Establishment Best Management Practices

- The area to be established should be properly prepared.
- Ensure erosion and sediment control devices are in place and properly maintained.
- Conduct a soil test before seeding to determine nutrient needs.
- Sprigs should be "knifed-in" and rolled to hasten root establishment.
- Sod should be topdressed to fill in the gaps between sod pieces and seams. This hastens establishment and provides a smoother surface.
- Use appropriate seeding methods for your conditions and ensure good seed to soil contact.
- When using sod, delay nutrient applications until sod has sufficiently rooted.
- When using sprigs, application rates for nitrogen, phosphorous, and potassium should correspond to percent ground cover (i.e. increasing rate as ground coverage increases).
- Slow-release nitrogen or light, frequent applications of soluble-nitrogen sources should be used during grow-in.
- Apply nutrients to the turf surface. Incorporating nutrients into the root zone does not result in more rapid establishment.
- Mow as soon as the sod has knitted-down, i.e. when sprigs have rooted at the second to third internode and seedlings have reached a height of one-third greater than intended height-of-cut. This will hasten establishment.

External Certification Best Management Practices

- Obtain and review materials to ascertain whether the facility should seek certification.
- Work with staff to establish facility goals that lead to certification.
- Establish goals to educate members about the certification program.

3 IRRIGATION

The supplemental use of water for course play and non-play areas is essential to supporting healthy turfgrass and sustaining optimal playability, aesthetics, marketability, and club membership participation. BMPs related to water use conserve and protect water resources. Conservation and efficiency-related efforts consider the strategic use of appropriate course and irrigation design, plant selection, computerized and data-integrated scheduling, and alternative water quality/supply options to maximize plant health and reduce the potential for negative impacts on natural resources (Figure 4). Water quality protection is an integrated approach that includes irrigation practices, pesticide and nutrient management, regulatory compliance measures, and structural measures as they concern environmental stewardship and policy.

Figure 4. Using wastewater for irrigation conserves potable water supplies. Photo Credit: Jamie Palokas.

Irrigation BMPs may also provide economic, regulatory compliance, and environmental stewardship advantages to those who utilize them within their irrigation management plan. BMPs are not intended to increase labor or place an undue burden on the owner/superintendent. If applied appropriately, BMPs can help stabilize labor costs, extend equipment life, limit repair and overall personal and public liability, and conserve water.

3.1 Regulatory Considerations

Golf course owners are responsible for contacting federal, state, and local water use authorities at the pre- and post-construction phases to determine annual or specific water consumption (water rights), permitting guidelines, and other regulatory requirements. Most uses of water in Delaware require a Water Allocation Permit (WAP) from DNREC. Permitted users with withdrawals (surface water or groundwater) exceeding 50,000 gallons per day are required to report monthly withdrawals to DNREC. Facilities within the Delaware River Basin are required to file annual surface water usage reports with the Delaware River Basin Commission.

An application for a water allocation permit must include a Drought Management Plan. Superintendents should be aware that the water allocation amounts are calculated to:

- Provide adequate water for the turf during a drought emergency based on historical rainfall.
- Protect the aquifer.

Superintendents should be aware that maintaining water levels in ponds for aesthetic purposes is not included in this calculation. If the resource is not adequate to maintain turf grasses during a

drought emergency, it must be addressed during the permitting process. This may also be the only viable opportunity to address the reuse of wastewater for turf grass irrigation.

3.2 Water Conservation and Efficient Use Planning

Potable water supplies in many areas of the United States are limited, and demand continues to grow. The challenge is to find solutions to maintain the quality of golf while using less water. Opportunities to conserve water exist when courses are initially designed and during renovation, during irrigation system design and use, and by incorporating the use of management zones (Figure 5).

Figure 5. Stormwater pond used for irrigation at Baywood Greens. Photo Credit: Jamie Palokas.

Some courses are designed using a "target golf" concept that minimizes the acreage of irrigated turf. If properly designed, water hazards and stormwater ponds can capture rain and runoff that may provide supplemental water under normal conditions; backup sources may be needed during severe drought. During times of intense heat stress, syringing, or the practice of applying a small amount of water to help cool the turfgrasses as it evaporates, may be beneficial under certain conditions. These conditions include turf with a very shallow root system, turf compromised by disease, poor soils, or wet-wilt. Because the cooling effect of syringing is very brief, repeated syringing and/or the use of fans will maximize the cooling effect.

In addition to utilizing well-adapted cultivars for in-play areas, existing golf courses can convert out-of-play area turf to naturally adapted native plants, grasses, or ground covers to reduce water use and augment the site's aesthetic appeal (Figure 6). Native plant species also provide wildlife with habitat and food sources, such as native flower areas that benefit pollinators. After establishment, site-appropriate plants normally require little to no irrigation. See the "Pollinator Protection" and "Landscape" chapters of this document for more information on native and drought tolerant plants.

Drought management plans should identify ways to achieve a 10% reduction in water use. For more guidance on developing a plan, see the USGA publication Developing a Drought Emergency Plan. Communication with water managers, golf club members, and the public

should be maintained to explain water conservation efforts as a proactive approach to addressing water-related issues.

Figure 6. Natural areas provide habitat and require less water and other inputs, as well as saving maintenance staff time. Photo Credit: John Jacob.

3.3 Irrigation Water Suitability

Golf course designers and managers should endeavor to identify and use alternative supply sources to conserve freshwater drinking supplies, promote plant health, and protect the environment. DNREC prepared a seminar detailing Beneficial Uses of Reclaimed Water in Delaware.

Studies of water supplies are recommended for irrigation systems, as are studies of waterbodies or flows on, near, and under the property. Water sources for irrigation must be dependable and offer sufficient resources to accommodate turf grow-in needs and ongoing maintenance. *Environmental Best Management Practices for Virginia's Golf Courses* describes the methodology and provides example calculations to determine water requirements using a seasonal and maximum bulk water requirement analysis (pages 37 and 38). In addition to quantity, the water quality must be suitable for plant growth and pose no threat to public health.

When necessary, include sodic water system treatment options in the budget to address water quality and equipment maintenance. Irrigation water that is high in soluble salts or sodium (Na^+) may result in a soil that has a high electrical conductivity (EC) leading to direct injury to turfgrass root and shoot tissues or manifest as negative effects on soil physical properties. High soil EC can result in osmotic drought or the inability of roots to absorb soil water. High Na^+ can disaggregate soils leading to poor water infiltration, restricted drainage and low soil oxygen.

Treatment options include flushing with clean water, along with core aeration and soil-test prescribed additions of gypsum.

3.4 Wellhead Protection

Wellhead protection is the establishment of protection zones and safe land-use practices around water supply wells in order to protect aquifers from accidental contamination. It includes protecting wellheads from physical impacts, keeping them secure, and sampling wells according to the monitoring schedule required by the regulating authority. Before installing new wells, DNREC and the local regulatory authorities should be contacted to determine the permitting and construction requirements and the required isolation distances from potential sources of contamination. Locate new wells up-gradient as far as possible from potential pollutant sources, such as petroleum storage tanks, septic tanks, chemical mixing areas, or fertilizer storage facilities.

3.5 Irrigation System Design

The irrigation system design should meet the site-specific needs identified by water quantity analyses and a thorough site assessment. The system's capacity to deliver water should not exceed the infiltration of the soils on site to avoid runoff. Though the design of an irrigation system is complex, some of the most important design decisions that influence the efficiency and effectiveness of water usage include those related to sprinkler and piping placement, sprinkler coverage and spacing, and communication options (Figure 7).

Figure 7. Computerized irrigation systems can improve irrigation efficiency and conserve water. Photo Credit: Erik Ervin.

A well-designed irrigation system should operate at peak efficiency and be designed and installed to improve water use efficiency by focusing on water placement and distribution. The design should maximize water use, reduce operational cost, conserve supply, and protect water resources. Detailed BMPs for irrigation system design are published by the Irrigation Association in 2014 in Landscape Irrigation Best Management Practices.

Pump stations should be efficient and sized to provide adequate flow and pressure. Equip pump stations with control systems that protect distribution piping, provide for emergency shutdown necessitated by line breaks, and allow maximum system scheduling flexibility. Consider variable frequency drive (VFD) pumping systems where feasible. These systems only expend enough energy to meet the demands of the irrigation pump(s). VFD systems reduce water hammer to fittings, pipes, and sprinklers when systems are pressurized.

3.6 Irrigation System Maintenance

Irrigation system maintenance on a golf course involves four major efforts: calibration and auditing, preventive maintenance, corrective maintenance, and record keeping. Personnel charged with maintaining a golf course irrigation system face numerous challenges. This is particularly true for courses with older or outdated equipment. Irrigation audits can be conducted to assess the system function, ensuring that the irrigation system works reliably and is cost effective. The Irrigation Association has published irrigation audit guidelines.

Figure 8. Irrigation system maintenance and repair conserves water and protects turfgrass. Photo Credit: John Jacob.

Good system management starts with proper utilization of preventive maintenance procedures and record keeping. Corrective maintenance is simply the act of fixing what is broken and may be as simple as cleaning a clogged orifice or as complex as a complete renovation of the irrigation system (Figure 8). As maintenance costs increase, an evaluation of whether a system renovation is needed should be conducted.

3.6.1 Irrigation Leak Detection

Irrigation systems are complex and should be closely monitored to ensure leaks are quickly detected and corrected. An irrigation system should also have high- and low-pressure sensors that shut down the system in case of breaks and malfunctions. Golf courses without hydraulic pressure-sustaining valves are much more prone to irrigation pipe and fitting breaks because of surges in the system, creating more downtime for older systems.

3.6.2 Irrigation System Renovation

Renovating a golf course irrigation system can improve system efficiencies, conserve water, improve playability, and lower operating costs.

3.6.3 Winterization and Spring Startup

Winterization of the irrigation system is important to protect the system and reduce equipment failures resulting from freezing. In the spring, inspecting the system for corrective maintenance issues and conducting a catch-can test to audit the system will ensure that the system is functioning properly.

3.6.4 Record Keeping

Careful record keeping is an important part of managing an irrigation system, as well as part of regulatory requirements for reporting water withdrawal.

3.7 Irrigation System Scheduling

An irrigation system should be operated based only on the moisture needs of the turfgrass -- or to water-in a fertilizer or chemical application as directed by the label. It should not run on a calendar-based schedule. Therefore, irrigation scheduling must consider soil infiltration and percolation rates as well as plant water requirements to determine the appropriate amount of irrigation to apply.

The goal of successful irrigation management is to limit excessive soil moisture while preventing wilt. Golf managers strive to precisely apply irrigation, so plant-available water is only slightly greater than predicted evapotranspiration (ET). For many highly maintained turf areas, like greens, small amounts of water should be applied as needed to replace what was lost. Soil moisture probes can help further improve irrigation precision. These technologies can guide irrigation head run times and identify locations that might benefit from additional hand watering (Figure 9).

Figure 9. Soil moisture sensors can improve irrigation decision making. Photo Credit: John Jacob.

For older systems utilizing electric/mechanical clocks that cannot automatically adjust for changing ET rates, frequent adjustment is necessary to compensate for the irrigation needs of individual turfgrass areas. In low-maintenance areas, such as golf course roughs, waiting until visual symptoms appear before irrigating is an acceptable method for determining irrigation needs. The amount to irrigate is important as well. Irrigating too shallowly encourages shallow rooting, increases soil compaction, and favors pest outbreaks while over-irrigating can lead to leaching and runoff. For golf greens and tees, the majority of the roots are in the top several inches of soil. Overall, use infrequent, deep irrigation to supply sufficient water for plants and to encourage deep rooting.

3.7.1 Sensor Technology

Install soil moisture sensors and other irrigation management tools in representative locations and maintain them to provide the information necessary for making good irrigation-management decisions. Rain gauges are necessary measurement tools to track how much rain has fallen at a specific site on the golf course. On some courses, more than one station may be necessary to get a complete measure of rainfall or evaporation loss. Use soil moisture probes, computer models, and tensiometers, as well as visual inspections for symptoms such as wilting turf, to supplement these measurements. Computerized displays are available to help visualize the system.

Predictive models based on weather station data and soil types are also available. These are relatively accurate and applicable, especially as long-term predictors of annual turf water requirements. Weather data such as rainfall, air and soil temperature, relative humidity, and wind speed are incorporated into certain model formulas, and soil moisture content is estimated. Models, however, are only as effective as the amount of data collected and the number of assumptions made. It is best to have an on-site weather station for daily weather information and ET rates to determine site-specific water needs.

Figure 10. Knowing the flow volume assists in irrigation system evaluation and scheduling. Photo Credit: Jamie Palokas.

3.7.2 Metering

Rainfall may vary from location to location on a course; incorporate the proper use of rain gauges, rain shut-off devices, flow meters, soil moisture sensors, and/or other irrigation management devices into the site's irrigation schedule. It is also important to measure the amount of water that is delivered through the irrigation system, via a water meter or a calibrated flow-measurement device (Figure 10). Knowing the flow or volume will help determine how well the irrigation system and irrigation schedule are working.

3.8 Irrigation Best Management Practices

Water Conservation Best Management Practices

- Select drought-tolerant varieties of turfgrass to minimize water use.
- Utilize hand watering or targeted irrigation only as needed, such as dry spots, to conserve water.
- During hot and dry weather, consider sequential applications of wetting agents to enhance water infiltration and achieve more uniform soil moisture availability.
- Control invasive plants or plants that require excessive water.
- Reduce the amount of irrigated area on the golf course, if possible, such as non-play areas.

- Identify opportunities to achieve water use reductions before mandatory water restrictions are enacted in times of drought.
- In times of drought, reduce mowing frequency to conserve water.
- During a drought, monitor the state's drought status to ensure compliance with restrictions.

Irrigation Water Suitability Best Management Practices

- Identify appropriate water supply sources that meet seasonal and bulk water allocations for grow-in and routine maintenance needs.
- Use alternative water supplies/sources that are appropriate and sufficiently available to supplement water needs and follow guidelines for use.
- Ensure that reclaimed, effluent, and other non-potable water supply mains have a thorough cross-connection and backflow prevention devices are in place and are operating correctly.
- Post signs in accordance with local utility and state requirements when reclaimed water is in use.
- Account for the nutrients in effluent (reuse/reclaimed) water when making fertilizer calculations.
- Monitor reclaimed water tests regularly for dissolved salt content.
- Routinely monitor shallow groundwater for saltwater intrusion or contamination by heavy metals and nutrients.
- Flush with fresh water or use amending materials regularly to move salts out of the root zone and/or pump brackish water to keep salts moving out of the root zone.
- Amend sodic water systems appropriately (with gypsum or an appropriate ion) to minimize sodium buildup in soil.
- Monitor sodium and bicarbonate buildup in the soil using salinity sensors.
- Monitor the quantity of water withdrawn to avoid impacting aquatic species.

Wellhead Protection Best Management Practices

- Surround new wells with bollards or a physical barrier to prevent impacts to the wellhead.
- Maintain records of new well construction and modifications to existing wells.
- Obtain a copy of the well log for each well to determine the local geology and well depth. These factors will have a bearing on how vulnerable the well is to contamination. Sample wells for contaminants according to the schedule and protocol required by DNREC.
- Inspect wellheads and the well casing at least annually for leaks or cracks. Have a Delaware-licensed well contractor make repairs as needed.
- Use backflow-prevention devices at the wellhead, on hoses, and at the pesticide mix/load station to prevent contamination of the water source.
- Properly plug abandoned or flowing wells.
- Never apply a fertilizer or pesticide next to a wellhead; consult product labels for additional requirements regarding application distance from wellhead.
- Never mix and load pesticides next to a wellhead if not on a pesticide mix/load pad; consult product labels for additional requirements regarding mixing and loading distance from wellhead.

- Have a Delaware-licensed well contractor properly seal abandoned or flowing wells.

Irrigation System Design Best Management Practices

- Create new and upgraded irrigation system designs to deliver water with maximum efficiency, focusing on precision water placement and distribution.
- Conduct a thorough site assessment prior to designing the irrigation system.
- Seek assistance from irrigation professionals, such as Certified Golf Course Irrigation System designers and WaterSense-certified irrigation consultants and follow established BMPs related to system design.
- Sprinkler placement should avoid interfering with the playability of the hole.
- Irrigation pipes should be installed away from the greens' surface to avoid substantial increases in repairs and damage should pipe failures occur.
- Update multi-head control systems with single-head control systems to conserve water and enhance efficiency.
- Manual quick-coupler valves should be installed for site-specific irrigation so such sites can be hand-watered during severe droughts.
- Install part-circle heads along lakes, ponds, wetlands margins, native areas, and tree trunks to avoid overspray of impervious areas such as roadways, sidewalks, and parking areas.
- Incorporate multiple nozzle configurations to add flexibility and enhance efficiency/distribution.
- Install VFD systems to lengthen the life of older pipes and fittings until the golf course can afford a new irrigation system.
- Use smaller horse power jockey or pm pumps to maintain pressure during periods of low flow to save electricity, reduce water hammer, and prolong the life of higher horsepower pumps.
- Include high- and low-pressure sensors that shut down the system in case of breaks and malfunctions in the irrigation system.
- Size the pumps to provide adequate flow and pressure.
- Equip pumps with control systems to protect distribution piping.
- Only qualified specialists should install the irrigation system.
- Construction and materials must meet existing standards and criteria.
- Construction must be consistent with the design.
- Installers must provide an accurate and comprehensive As-Built map.

Irrigation System Maintenance Best Management Practices

- Examine turf quality and plant health for indications of irrigation malfunction or the need for scheduling adjustments.
- Evaluate pressure and flow to determine that the correct nozzles are being used and that the heads are performing according to manufacturer specifications.
- Visually inspect the entire system to identify necessary repairs or corrective actions and make repairs before carrying out other levels of evaluation.
- Conduct an annual irrigation audit to facilitate a high-quality maintenance and scheduling program for the irrigation system.

- Inspect the system daily for proper operation by checking computer logs and visually inspecting the pump station, remote controllers, and irrigation heads. Carry out a visual inspection for leaks, misaligned or inoperable heads, and chronic wet or dry spots so that adjustments can be made.
- Observe the system in operation regularly to detect controller or communication failures, stuck or misaligned heads, and clogged or broken nozzles.
- Check filter operations frequently. Keeping filters operating properly prolongs the life of an existing system and reduces pumping costs.
- Monitor the power consumption of pump stations for problems with the pump motors, control valves, or distribution system.
- Increase frequency of routine inspection/calibration of soil moisture sensors that may be operating in high-salinity soils.
- Inspect irrigation pipes and look for fitting breaks caused by surges in the system.
- Install thrust blocks to support conveyances.
- Maintain air-relief and vacuum-breaker valves.
- Have qualified pump personnel perform regular checks of amperage to accurately identify increased power usage that indicates potential problems.
- Check application/distribution efficiencies annually.
- Document equipment run-time hours.
- Document and periodically review the condition of infrastructure, such as pipes, wires, and fittings.
- Follow manufacturer recommendations for system checks and routine maintenance.
- Routinely inspect the system for proper operation by checking computer logs and visually inspect the pump station, remote controllers, and irrigation heads.
- Flush irrigation lines regularly to minimize emitter clogging. To reduce sediment buildup, make flushing part of a regular maintenance schedule. If fertigating, prevent microbial growth by flushing all fertilizer from the lateral lines before shutting down the irrigation system.
- Check filter operations frequently. An unusual increase in the amount of debris may indicate problems with the water source.
- Clean and maintain filtration equipment.
- Keep records of filter changes, as this could be an early sign of system corrosion, well problems, or declining irrigation water quality.

Irrigation Leak Detection Best Management Practices

- Monitor water meters or other measuring devices for unusually high or low readings to detect possible leaks or other problems in the system. Make any needed repairs.
- Monitor the system daily for malfunctions and breaks. Log water usage daily.
- Ensure that control systems provide for emergency shutdowns caused by line breaks and allow maximum system scheduling flexibility.

Irrigation System Renovation Best Management Practices

- Determine the age of the system to establish a starting point for renovation.
- Identify problems and their costs to determine which renovations are appropriate.
- Identify system performance improvements that maximize the efficient use of the current system.

- Evaluate the cost of renovation and its financial and management benefits.

Winterization and Spring Start Up Best Management Practices

- Conduct a visual inspection of the irrigation system: inspect for mainline breaks, low pressure at the pump, and head-to-head spacing.
- Flush and drain above-ground irrigation system components that could hold water.
- Remove water from all conveyances and supply and distribution devices that may freeze by using compressed air or opening drain valves at the lowest point on the system.
- Clean filters, screens, and housings. Remove drain plugs and empty water out of the system.
- Secure systems and close and lock covers/compartment doors to protect the system from potential acts of vandalism and from animals seeking refuge.
- Remove drain plugs and drain above-ground pump casings.
- Record metering data before closing the system.
- Secure or lock irrigation components and electrical boxes.
- Perform pump and engine servicing/repair before winterizing.
- Recharge irrigation system in the spring with water and inspect for corrective maintenance issues.
- In the spring, conduct a catch-can test to audit the system.

Record Keeping Best Management Practices

- Keep records of filter changes, as this could be an early sign of system corrosion, well problems, or declining irrigation water quality.
- Document equipment run-time hours. Ensure that all lubrication, overhauls, and other preventive maintenance are completed according to manufacturer schedule.
- Monitor and record the amount of water being applied, including system usage and rainfall and identify areas where minor adjustments can improve performance.
- Document and periodically review the condition of infrastructure, such as pipes, wires, and fittings. If the system requires frequent repairs, it is necessary to determine why these failures are occurring.
- Document all corrective actions.
- Adhere to all regulatory reporting requirements for water withdrawal.

Irrigation System Scheduling Best Management Practices

- Reset irrigation controllers/timers as often as practically possible to account for plant growth requirements and local climatic conditions.
- Use properly calibrated flow meters, soil moisture sensors, rain shut-off devices, and/or other automated methods to manage irrigation.
- Do not allow irrigation rates to exceed the maximum ability of the soil to absorb and hold the water applied at any one time.
- Base irrigation on ET rates and soil moisture replacement, not on a calendar-based schedule.
- Install computerized control systems on all new course irrigation systems to help ensure efficient irrigation application. These allow for timing adjustments at every head.
- Place rain shut-off devices and rain gauges in open areas to prevent erroneous readings.
- Use multiple soil moisture sensors/meters for accuracy and to reflect soil moisture levels.

- Calibrate soil moisture sensors regularly.

Sensor Technology Best Management Practices

- The reliability of older clock-control station timing depends on the calibration of the timing devices; this should be done periodically, but at least seasonally.
- Shut off an irrigation system after 0.25 to 0.5 inches of rain falls.
- Avoid use of a global setting; adjust watering times per head.
- Place permanent irrigation sprinklers and other distribution devices according to manufacturer recommendations.
- Base spacing on average wind conditions during irrigation.
- Install wireless soil moisture systems to prevent damage from aeration.
- Use soil moisture sensors to bypass preset schedules or for on-demand irrigation.
- Use multiple soil moisture sensors to reflect soil moisture levels.
- Place soil moisture sensors in the root zones of representative locations within each irrigation zone and in the driest irrigation zone of the irrigation system.
- Base irrigation run times on actual site conditions for each head and zone and adjust as needed based on current local meteorological data.
- Use the computed daily ET rate to adjust run times to meet the turf's moisture needs.
- Manually adjust automated ET data to reflect wet and dry areas on the course.
- Do not let irrigation quantities exceed the available moisture storage in the root zone.
- Time the irrigation schedule to coincide with other management practices, such as the application of nutrients, herbicides, or other chemicals.
- Irrigate in the early morning hours before air temperatures rise and relative humidity drops.
- Visually monitor for localized dry conditions or hot spots to identify poor irrigation efficiency or a failed system device.

Metering Best Management Practices

- Calibrate equipment periodically to compensate for wear in pumps, nozzles, and metering systems.
- Use properly calibrated flow meters, soil moisture sensors, rain shut-off devices, and/or other automated methods to manage irrigation.
- Use flow meters with a run of pipe that is straight enough — both downstream and upstream — to prevent turbulence and bad readings.
- Use flow meters to determine how much water is applied.

4 SURFACE WATER MANAGEMENT

Whether natural or manmade, surface water in the form of lakes, ponds, and streams has long been associated with golf courses. Natural lakes and ponds are usually associated with existing water sources, such as wetland areas. Irrigation impoundments (lakes, ponds, and constructed wetlands) can be incorporated into the design of a course and used both to manage stormwater and to function as a source for irrigation. Overall, surface water management incorporates not only the information contained in this chapter, but many of the issues discussed throughout this document, including:

- design considerations such as the use of vegetated buffers
- fertilization strategies near surface waters
- pesticide usage
- water quality monitoring

When golf courses are designed and built, their drainage capability concept is guided by an average rainfall event of a given frequency. For example, a golf course drainage system is typically designed to retain a two- or five-year rain event, reasonably draining the precipitation in a matter of hours, with excess water that has not infiltrated into the ground retained temporarily until it leaves the property. In some instances, golf courses are mandated to handle a 20-, 50-, or 100-year rain event, which means the golf course must retain more water, potentially for a longer period of time. This ability to retain large amounts of water requires accurate engineering and extensive construction to prevent physical or financial damage to the facility. Many BMPs prolong the retention process as long as practical, retaining as much of the stormwater in surface or underground storage as is reasonable, and may even improve the quality of water leaving the property.

Except for temporary retention ponds, most aquatic areas require their own management plan and regular attention. Important components of aquatic maintenance include managing aquatic habitats, such as the aquatic algae and plant growth and dissolved oxygen; reducing or preventing nutrient and sediment enrichment especially through the use of vegetated buffers; and ensuring adequate dissolved oxygen levels to sustain aquatic life.

4.1 Regulatory Considerations

Course owners and superintendents should thoroughly investigate all regulatory requirements that apply to the golf facility to protect water quality and to manage stormwater. DNREC sets standards for the level of protection afforded to each body of surface water in the state (see State of Delaware Water Quality Standards, 2014). Water quality standards protect and enhance surface water quality, protect public health and welfare, protect aquatic resources, and serve the purposes of the federal Clean Water Act (CWA) and all its amendments. In practice, Delaware's water quality standards form the basis for state programs that control the amount of pollutants entering waters from such sources as industrial plants, sewage treatment plants, storm sewers, and runoff from urban and rural areas. For more information on state programs related to surface

water quality, see DNREC's Surface Water Quality Standards. Water quality information can be found in DNREC's Water Quality Monitoring Network Data Portal.

Surface waterbodies not meeting surface water quality standards may be subject to pollution limits, also known as the Total Maximum Daily Load (TMDL). TMDLs establish the maximum amount of an impairing substance or stressor that a waterbody can assimilate and still meet water quality standards and allocates the pollutant load among pollution contributors. TMDLs are a tool for implementing state water quality standards and are based on the relationship between pollution sources and in-stream water quality conditions. Detailed information on Delaware's TMDLs can be found in the state's 2016 Combined Watershed Assessment Report (305(b)) and Determination for the Clean Water Act Section 303(d) List of Waters Needing TMDLs.

TMDLs have been set to fully restore the health of the Chesapeake Bay. The Environmental Protection Agency (EPA) established pollution load limits to restrict three major pollutants in the Bay watershed: nitrogen and phosphorus (nutrients) and sediment (soil). These load limits, which set clear goals for reducing excess pollution, are science-based estimates of the amount of each substance the Chesapeake Bay and its tributaries can receive and still meet standards for clean, healthy water. The goals, or pollution reduction targets, require the seven jurisdictions in the Chesapeake Bay watershed (Maryland, Virginia, Pennsylvania, Delaware, West Virginia, New York and the District of Columbia) to reduce their nutrient and sediment loadings to the Bay until these protective limits are met, within a specific time frame.

In response to these TMDLs, the seven Bay jurisdictions created individual Watershed Implementation Plans (WIP), or restoration blueprints, that detail specific actions each would take to meet their pollution reduction goals by 2025. These WIPs have been developed in three phases, with each successive WIP increasing the level of detail of load goals and actions to achieve those goals. Delaware's Phase II WIP was published in 2012; the Phase III WIP is due to EPA in 2019. The blueprints guide local and state Bay restoration efforts through the next decade and beyond.

Delaware has developed comprehensive programs for stormwater management and for erosion and sediment control that are designed to reduce the adverse impacts of development on stormwater runoff. This program addresses both the temporary and permanent impacts associated with development activities. New development projects must follow regulatory requirements that allow runoff to infiltrate through the soil and recharge groundwater supplies. Post construction stormwater management practices must be designed, constructed and maintained in accordance with Sections 11.0 and 12.0 of the 7 DE Admin Code 5101 Delaware Sediment and Stormwater Regulations. The regulatory guidance document "Standards and Specifications for Post Construction Stormwater Management BMPs" offers additional guidance in the design, construction and maintenance of stormwater BMPs.

4.2 Stormwater Management

The control of stormwater on a golf course is more than just preventing the flooding of the clubhouse, maintenance sites, and play areas. Proper management of stormwater controls the

amount and rate of water leaving the course, controls erosion and sedimentation, stores irrigation water, removes waterborne pollutants, enhances wildlife habitat, and addresses aesthetic and playability concerns. Stormwater runoff (also called surface runoff) is the conveying force behind what is called non-point source pollution. Non-point source pollution is caused by water moving over and through the ground, picking up and carrying away natural and human-made pollutants, and finally depositing them into surface waters (lakes, rivers, wetlands, coastal waters) and groundwater. On golf courses, pollutants that might be found in surface runoff include, but are not limited to, pesticides, fertilizers, sediment, and petroleum.

Treating stormwater to avoid impacts to water quality is best accomplished by a treatment train approach in which water is conveyed from one treatment to another by conveyances that themselves contribute to the treatment. These treatments include source controls, structural controls, and non-structural controls. Source controls are the first car of the BMP treatment train. They help prevent the generation of stormwater runoff or the introduction of pollutants into stormwater runoff. The most effective method of stormwater treatment is to prevent or preclude the possibility of movement of sediment, nutrients, or pesticides in runoff.

The next car in the treatment system is often structural controls, which are design and engineering features of the course created to remove, filter, detain, or reroute potential contaminants carried in surface runoff (Figures 11 and 12). Examples of structural BMPs include infiltration basins, stormwater ponds, constructed wetlands, and filters to address water quality, water recharge, and stream channel protection. Non-structural controls mimic natural hydrology and minimize the generation of excess stormwater and include vegetated systems. Vegetated systems such as stream buffers act as natural biofilters, reducing stormwater flow, removing sediments from surface water runoff, and preventing nutrient and pesticide discharge in runoff from reaching surface waters (Figure 13). The treatment train approach combines these controls, as in the following example: Stormwater can be directed across vegetated filter strips (such as turfgrass), through a swale into a wet detention pond, and then out through another swale to a constructed wetland system.

Figure 11. Retention areas allow stormwater to infiltrate into the ground. Photo Credit: John Jacob.

Figure 12. The retention area is usually empty of water. Photo Credit: Erik Ervin.

Figure 13. Buffer areas around wetlands, such as around these tidal wetlands at Baywood Greens, protects water quality. Photo Credit: Jamie Palokas.

During any construction or redesign activity, proper erosion and sedimentation control must be followed (as discussed in the "Planning, Design, and Construction" chapter) to ensure that stormwater runoff does not impact water quality. Properly designed golf courses capture rain and runoff in water hazards and stormwater ponds, providing most or all of the supplemental water necessary under normal conditions, though backup sources may be needed during drought conditions.

4.3 Floodplains

Re-establishment of natural water systems helps mitigate flooding and control stormwater. Therefore, high sediment and nutrient loads should be addressed, as well as vertical and lateral stream migration, which causes unstable banks, flooding, and reductions in groundwater recharge. Land use decisions and engineering standards must be based on the latest research science available.

4.4 Wetlands

The biological activity of plants, fish, animals, insects, and especially bacteria and fungi in a healthy, diverse wetland is the recycling factory of our ecosystem. While wetlands do pose a special concern, their mere presence is not incompatible with environmentally sound golf courses. With care in design and management, many golf holes have been threaded through sensitive areas. When incorporated into a golf course design, wetlands should be maintained as preserves and separated from managed turf areas with native vegetation or structural buffers. In addition, constructed or disturbed wetlands can be designed and permitted as an integral part of the stormwater management system.

4.5 Lakes and Ponds

Most golf courses plan their lakes and water hazards to be a part of the stormwater control and treatment system. However, natural waters of the state cannot be considered treatment systems and must be protected. Lakes and ponds may also be used as a source of irrigation water. Therefore, it is important to consider these functions when designing and constructing the ponds. Peninsular projections and long, narrow fingers may prevent mixing. Ponds that are too shallow may reach high temperatures, leading to low oxygen levels and promoting algal growth and excess sedimentation.

The management of lakes and ponds should include a clear statement of goals and priorities to guide the development of the BMPs necessary to meet those goals. Some of the challenges facing superintendents in maintaining the quality of golf course ponds are as follows:

- low dissolved oxygen (DO) levels
- sedimentation
- changes in plant populations
- nuisance vegetation
- nuisance waterfowl
- maintenance of littoral shelves
- vegetation on the lakeshore

Nutrient enrichment from nitrogen, phosphorus, and sediments in surface water runoff can increase the growth of aquatic plants, algae, and bacteria in ponds. Therefore, one of the most important BMPs is to maintain a riparian buffer around surfaces waters to filter the nutrients and sediments in runoff. In fact, the DNREC calls vegetated buffers around a lake or pond "the single, most valuable management practice." The DNREC recommends a 15- to 20-foot wide area around waterbodies that is left unmowed or mowed only once or twice a year so that grasses and plants grow knee-high (Figure 13). In addition to allowing silt and nutrients to drop before reaching surface waters, these buffer strips also discourage geese from taking up residence, as they prefer shorter grassy areas. For more information, see the DNREC's *Best Management Practices for Small Ponds.*

Delaware's nutrient management regulations specify that fertilizers cannot be applied within 15 feet of waterways. This setback is reduced to 10 feet if a drop spreader, rotary spreader with deflector, or targeted spray liquid is used to apply fertilizer.

4.5.1 Dissolved Oxygen

DO is the amount of oxygen that is present in water and is measured in milligrams per liter (mg/L). Adequate DO levels are required to sustain life in aquatic organisms and vary by species, the organism's life stage, and water temperature. The amount of DO that water can hold depends on the physical conditions of the body of water (water temperature, rate of flow, oxygen mixing, etc.) and photosynthetic activity. Colder water has higher DO levels than warmer water. DO levels will also differ by time of day and by season as water temperatures fluctuate. Similarly, a difference in DO levels may be seen at different depths in deeper surface waters if the water stratifies into thermal layers. Aerators can be used to increase DO levels in shallow water bodies (Figure 14).

Figure 14. Aerators can be used to maintain dissolved oxygen in shallow water bodies. Photo Credit: John Jacob.

Flow rates influence DO levels. For example, fast-flowing streams hold more oxygen than impounded water. Photosynthetic activity also influences DO. As aquatic plants and algae photosynthesize during the day, they release oxygen. At night, photosynthesis slows down considerably or even stops, and algae and plants pull oxygen from the water. In impoundments with excessive plant and algae growth, several cloudy days in a row can increase the potential for fish kills during warm weather. Therefore, preventing excessive aquatic growth by preventing nutrient enrichment will help maintain DO levels.

4.5.2 Aquatic Algae and Plants

Phytoplankton, or algae, give water its green appearance and provide the base for the food chain in ponds. Tiny animals called zooplankton use phytoplankton as a food source. Large aquatic plants (aquatic macrophytes) can grow rooted to the bottom and supported by the water (submersed plants), rooted to the bottom or shoreline and extended above the water surface (emersed plants), rooted to the bottom with their leaves floating on the water surface (floating-leaved plants), or free-floating on the water surface (floating plants).

These different types of aquatic macrophytes can have different functions that protect water quality. Aquatic plants growing on a littoral shelf may help protect receiving waters from the pollutants present in surface water runoff. In open areas, floating-leaved and free-floating plants suppress phytoplankton because they absorb nutrients from the pond water and create shade. For

more information on managing aquatic plants and algae in ponds in Delaware, see the DNREC Division of Fish and Wildlife web page about Aquatic Plants and Herbicides. See *Recommended Herbaceous Plants for Stormwater Management Ponds in Delaware* for Delaware-specific native aquatic plant recommendations.

Use of grass carp for aquatic weed control is governed by DNREC policy and limited to C*tenopharyngodon idella*, a functionally sterile form.

4.5.3 Waterfowl

The deposits of fecal matter by resident and migrating waterfowl (such as Canada geese) can substantially impact water quality through nutrient enrichment. On golf courses, shallow ponds with significant populations of waterfowl are most likely to be affected. In addition, large numbers of Canada geese can erode shorelines and thin the grass cover on greens and fairways, contributing to the potential for erosion. Once geese have become established, efforts to control them have met with mixed success. Loud sounds, dogs, and hunting have been tried in order to deter them. USDA goose round-ups and depredation permits can also be acquired to manage goose populations. However, many of these efforts do not lend themselves to golf courses, especially in more urban areas. For more information, see also *Canada Goose Management Series: Harassment* from Rutgers University.

4.6 Water Management Best Management Practices

Stormwater Management Best Management Practices

- Design stormwater treatment trains.
- Install berms and vegetated swales to capture pollutants and sediments from runoff before it enters irrigation storage ponds or other surface waters.
- Implement no- or low-maintenance vegetated buffer strips around surface waters.
- Utilize vegetated filter strips in conjunction with water filtration basins.
- Eliminate or minimize directly connected impervious areas.
- Use depressed landscape islands in parking lots to catch and filter water and allow for infiltration. When hard rains occur, an elevated stormwater drain inlet allows the island to hold the treatment volume and settle out sediment, while allowing the overflow to drain away.
- When possible, maximize the use of pervious pavements, such as brick or concrete pavers separated by sand and plants.

Floodplains Best Management Practices

- Install stream buffers to restore natural water flows and flooding controls.
- Install buffers in play areas to stabilize and restore natural areas that will attract wildlife species.
- Install detention basins to store water and reduce flooding at peak flows.

Wetlands Best Management Practices

- Maintain appropriate silt fencing on projects upstream to prevent erosion and sedimentation.
- Natural waters cannot be considered treatment systems and must be protected. (Natural waters do not include treatment wetlands.)
- Establish a low- to no-maintenance level within a 75-foot buffer along nontidal and tidal wetlands.
- Establish and maintain a 100-foot riparian buffer around wetlands, springs, and spring runs.

Lake and Pond Best Management Practices

- Maintain a 15-20 foot unmowed, vegetated buffer strip (riparian buffer) to filter the nutrients and sediment in runoff. Leave unmowed or mow only once or twice a year so that grasses and plants grow knee-high.
- If mowing near a pond or lake, collect clippings or direct them to upland areas so they do not increase nutrient loading to waterbodies.
- Maintain the required setback distance when applying fertilizers near waterways.
- Encourage clumps of native emergent vegetation at the shoreline.
- Maintain water flow through lakes if they are interconnected.
- Establish wetlands where water enters lakes to slow water flow and trap sediments.
- Maintain appropriate erosion and sedimentation controls on projects upstream to prevent sedimentation and nutrient enrichment to waterbodies.
- Dredge or remove sediment before it becomes a problem.

Dissolved Oxygen Best Management Practices

- Establish DO thresholds to prevent fish kills, which occur at levels of 2-3 mg/L.
- Reduce stress on fish by keeping DO levels above 5 mg/L.
- Manipulate water levels to prevent low levels that result in warmer temperatures and lowered DO levels.
- Use artificial aeration (diffusers) if needed to maintain adequate DO.

Aquatic Algae and Plants Best Management Practices

- In ponds with littoral plantings, problem plants should be selectively controlled without damaging littoral shelves.
- Encourage clumps of native emergent vegetation at the shoreline.
- A comprehensive management plan should include strategies to control the growth of nuisance vegetation that can negatively affect a pond's water quality and treatment capacity.
- Frequently remove filamentous algae by hand and/or frequently apply algaecide to small areas of algae (spot treatment).
- Use algaecides containing hydrogen peroxide instead of copper or endothall to reduce the risk of oxygen depletion.

- To control excessive aquatic plant growth, mechanical methods can be used that include the placement of barriers such as plastic mesh to block sunlight penetration into the pond, and physically pulling, raking, and cutting weeds. Aquatic herbicides, if used to control excessive aquatic plant growth, require a permit.

5 GROUNDWATER PROTECTION

Groundwater in Delaware is plentiful, and a majority of the state's citizens use it as drinking water. Groundwater is the sole source of drinking water for approximately 65% of the state's population, specifically residents south of the Chesapeake and Delaware Canal in southern New Castle, Kent, and Sussex counties. North of the canal, approximately 30% of public water come from groundwater and the remainder from surface water.

Though plentiful, groundwater in Delaware is a vulnerable resource due to geology: the shallow depth to groundwater (typically less than 10 feet in Delaware) and the permeability of the subsurface material. Because of these characteristics, the Delaware Department of Agriculture's Pesticide Section began monitoring the state's shallow groundwater for pesticides in 1995. The department monitors a network of just over 100 dedicated monitoring wells and screens samples for pesticides commonly used in agriculture and the commercial industry. While the majority of the wells have tested negative, some pesticides have been detected above reporting levels. Therefore, preventing leaching and protecting wellheads are important aspects of golf course management that help protect drinking water sources.

5.1 Regulatory Considerations

The Ground Water Protection Branch of the Water Supply Section of DNREC is responsible for the groundwater protection program, the source water assessment and protection program, and the wellhead protection program for the state. Responsibilities include regulatory review, resource assessment, database quality control, and public education. The regulatory authority includes the location, design, installation, use, disinfection, modification, repair, and sealing of all wells and associated pumping equipment as well as prescribing certain requirements for the protection of public and private potable water supply wells under Title 7301 Regulations Governing the Construction and Use of Wells.

The Water Allocation Branch of the Water Supply Section of DNREC regulates water withdrawals in the state under Title 7303 Regulations Governing the Allocation of Water. Permits are required for withdrawals greater than 50,000 gallons per day from any surface or groundwater source. If a withdrawal is in the jurisdiction of the Delaware River Basin Commission (DRBC) and will withdraw more than 100,000 gallons per day, a separate approval from the DRBC is also required. All wells in Delaware must be constructed by a well driller or well driver licensed with DNREC. New irrigation ponds require a permit, which can be obtained with an application for a permit to construct a water impoundment.

Permit holders are required to record and report water usage each year. Golf courses must report monthly production for each water facility (well or intake) and a system summary of total monthly production. Other information such as water transfers and leak-losses are also required to be reported. For more information on reporting requirements, see the Water Supply – Water Allocation Branch web page.

Wellhead protection programs restrict land-use activities within protection areas for public drinking water wells. Local ordinances should be reviewed to determine the location of these protected areas and all relevant regulations should be communicated to staff and followed as required.

5.2 Preventing Leaching

Leaching refers to the loss of water-soluble plant nutrients or chemicals from the soil as water moves through the soil profile and reaches the saturated zone. Some of the factors that can influence leaching potential include the depth to groundwater, soil type and structure (e.g. sandy soils), geology, rate of precipitation, and amount of irrigation. Especially in areas with high recharge rates (most of Delaware), irrigation should only be sufficient to reach the root depth. More information on making irrigation decisions can be found in the "Irrigation" chapter of this document.

When applying fertilizers or pesticides, the rate, timing, and location of applications should be considered to minimize the potential for losses due to leaching. Sandy soils, for example, have a low potential to fix phosphorus and therefore are more likely to leach phosphorus. Nitrogen, in the form of nitrate (NO_3-N) presents leaching concerns for groundwater quality. Fertilizers with solubility >30 mg/L (or 30 ppm) can pose a risk for leaching.

The potential for pesticides to leach to groundwater depends on many factors, such as those described above. In addition, pesticide properties, such as solubility, influence leaching potential (Table 2). Because of the increased potential for leaching in Delaware due to the state's high water table and sandy soils, the Delaware Department of Agriculture (DDA)'s Groundwater Monitoring Program has been monitoring for pesticide contamination in groundwater since 1995.

Table 2. Threshold values indicating potential for groundwater contamination by pesticides

Chemical or Physical Property	Threshold Value
Water solubility	Greater than 30 ppm
Henry's Law Constant	Less than lO-2 atm to m-3 mol
Kd	Less than 5, usually less than 1 or 2
Koc (Soil Adsorption)	Less than 300 to 500
Hydrolysis half-life	More than 25 weeks
Photolysis half-life	More than 1 week
Field dissipation half-life	More than three weeks

Source: USEPA, 1986, Pesticides in Groundwater

5.3 Protecting Water Supplies

The Source Water Assessment and Protection Program (SWAPP) delineates the wellhead protection areas for all public wells in Delaware and posts them to FirstMap Delaware. Within wellhead protection areas, land-use activities are restricted that could otherwise adversely affect the quantity or quality of groundwater moving toward the wells or well fields. Superintendents should also be aware of any local ordinances that restrict land-use activities in these areas.

Before installing new wells, DNREC and the local regulatory authority should be contacted to determine permitting and any setback requirements. The Delaware SWAPP will meet with applicants to do a preliminary site review to look at well placement with respect to any identified potential sources of contamination that may be in the area (if requested). New wells should be located up-gradient as far as possible from potential pollutant sources, such as petroleum storage tanks, septic tanks, chemical mixing areas, and fertilizer storage facilities. Most pesticide labels now prohibit mixing/loading pesticides within 50 feet (or other specified setback distances) from any well. Pesticide users are required by federal law to follow all restrictions on the pesticide label; users must read the label to determine what restrictions, if any, are in place regarding mixing/loading and applying pesticides around wellheads. Licensed water-well contractors are needed to drill new wells, which must meet regulatory and code requirements.

5.4 Groundwater Protection Best Management Practices

Preventing Leaching Best Management Practices

- Identify areas on the course that may be prone to leaching (shallow depth to groundwater, sandy soils, etc.)
- Manage irrigation to avoid over-watering.
- Consider the potential for fertilizers or pesticides to leach before applying.

Wellhead Protection Best Management Practices

- Use backflow-prevention devices at the wellhead, on hoses, and at the pesticide mix/load station to prevent contamination of water sources.
- Follow pesticide labels for setback distance requirements (typically a minimum of 50 feet).
- Properly decommission illegal, abandoned, or flowing wells.
- Surround new wells with bollards or a physical barrier to prevent impacts to the wellhead.
- Inspect wellheads and the well casing routinely for leaks or cracks; make repairs as needed.
- Maintain records of new well construction and modifications to existing wells.
- Obtain a copy of the well log for each well to determine the local geology and the well's depth; these factors will have a bearing on how vulnerable the well is to contamination.
- Develop a written plan that minimizes environmental risk and potential contamination to wellheads.

6 WATER QUALITY MONITORING

Aligning golf course management practices with BMPs protects water quality on and downstream from the facility. A water quality monitoring program can confirm the effectiveness of a BMP-based program and can provide important feedback on areas needing improvement. Water quality monitoring can be used to determine whether outside events are changing the quality of water entering the golf course or whether the golf course is having a positive, neutral, or negative effect on water quality. It also can provide a body of evidence of the golf course's environmental impact. Monitoring demonstrates a commitment both to water quality and to implementing BMPs that protect water resources downstream. Furthermore, providing monitoring information to local, regional, and state regulatory authorities and watershed groups can help foster positive relationships with these stakeholders.

The following sections of this chapter provide an overview of establishing a water quality monitoring program. More detailed information on developing a water quality monitoring program for golf courses has been published in *Environmental Best Management Practices for Virginia's Golf Courses*, which also provides an example of a water quality monitoring report in Appendix A.

6.1 Regulatory Considerations

Surface water quality is regulated under the CWA. DNREC monitors water quality to determine compliance with its water quality standards. Surface water monitoring on golf courses is not a regulatory requirement, but it does demonstrate to regulators and the interested public the role of golf course superintendents in protecting the state's natural resources. The results of any monitoring programs should be compared with Title 7401, Delaware Surface Water Quality Standards.

6.2 Existing Water Quality Information

Golf course superintendents seeking to develop and implement a monitoring program to document water quality conditions should first review available baseline water quality data. Baseline data can be assessed to determine the likely origin of contaminants, measure the extent of sedimentation and nutrient inputs, and estimate the potential impacts to surface water and groundwater. A number of state and federal programs monitor surface water and groundwater quality:

- DNREC's Surface Water Quality Monitoring Program maintains a General Assessment Monitoring Network of about 140 stations throughout the state.

- The Delaware Department of Agriculture's Pesticide Section, with the assistance of the Delaware Geological Survey, has established a network of groundwater monitoring wells throughout the state south of the Chesapeake and Delaware Canal. These wells are used primarily to monitor the state's groundwater for pesticides.

- The United State Geological Survey (USGS) monitors surface water and groundwater throughout the US, including maintaining monitoring wells and stations in Delaware.

- The Delaware Nature Society maintains a network of monitoring sites using citizen volunteers to collect physical, chemical and biological data in a number of watersheds in the state.

Data from these monitoring programs are available online at the following sites:

- Delaware Water Quality Portal
- Delaware Groundwater Monitoring Program for Pesticides
- National Ground-Water Monitoring Network
- USGS Surface Water Data for Delaware
- Delaware Nature Society StreamWatch Watershed Data Center

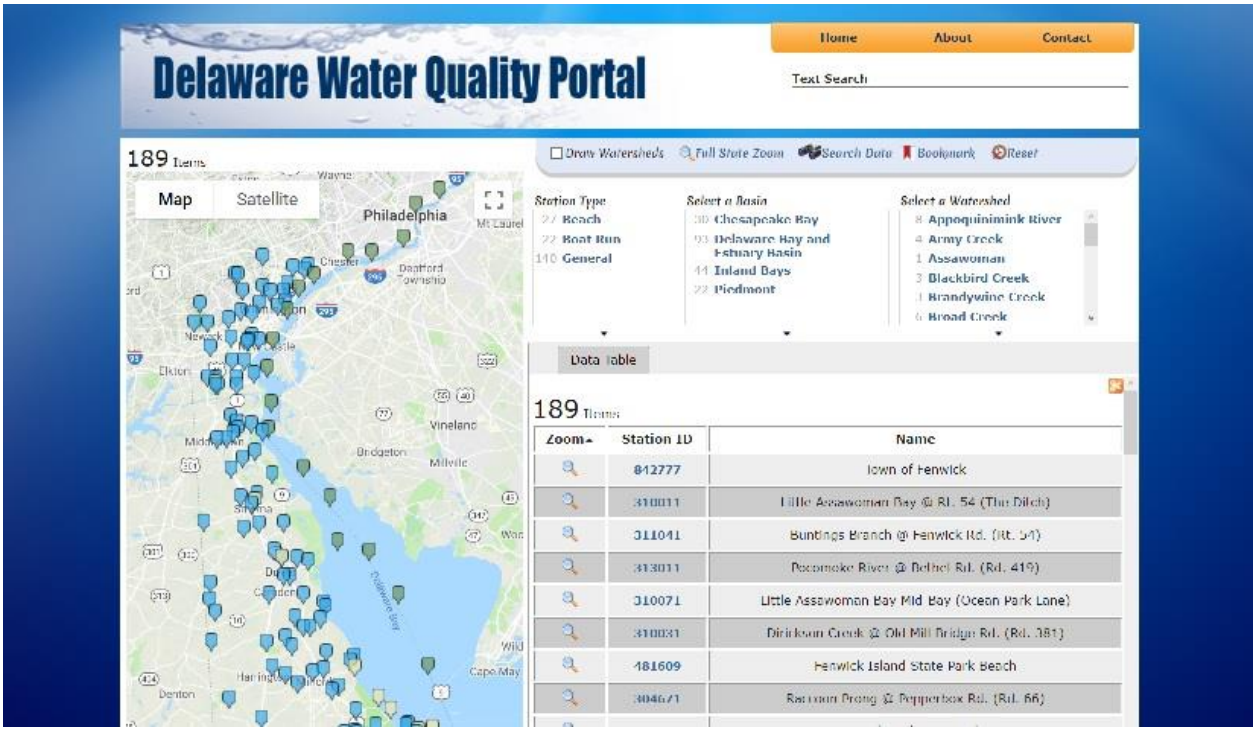


Figure 15. The Delaware Water Quality Portal can provide water quality information for developing a monitoring program.

6.3 Developing a Water Quality Monitoring Program

A water quality program begins with the development of a monitoring plan. The plan should identify site-specific characteristics such as the watershed, stream flows, soil type, topography, and drainage. The plan should also identify the monitoring objectives, locations, frequency and parameters. Baseline reference conditions can be established by collecting upstream water samples and comparing them with collection sites downstream of the areas influenced by golf

course management practices and/or reviewing existing water quality data from representative locations.

Surface water collection sites can include streams, rivers, ponds, wetlands, etc., with the number and location of collection sites dependent upon monitoring objectives. For example, a simple monitoring program can consist of the collection of DO data in surface waterbodies to ensure that these waterbodies can support aquatic life. A more comprehensive monitoring program should include both field measurements (pH, temperature, DO, etc.) and analytical testing (e.g. nitrates, phosphorus, total dissolved solids, etc.). An extensive program could include the collection of macroinvetebrate data. Regardless of the extent of the monitoring program, the location of monitoring sites should remain consistent over time to establish trends in data. Facilities could consider partnering with schools, universities or non profit organizations (such as the Delaware Nature Society's StreamWatch program) to develop a monitoring program.

In some instances, groundwater monitoring may be desired. Groundwater monitoring from wells located at the hydrologic entrance and exit from the course may be the best way to evaluate a golf course's impact on water quality. If groundwater monitoring data from these locations are not available from existing sources, monitoring wells at the hydrologic entrance and exit from a course can be installed by private companies. Groundwater quality parameters can be limited to test only the ones directly influenced by course management, such as levels of pesticides and organic and inorganic nitrogen. DNREC regulates the installation of monitoring and observation wells. For further information, see the general guidelines and information published by DNREC.

Water quality monitoring of irrigation sources (particularly water supply wells and storage lakes) provides valuable agronomic information that can influence nutrient programs. Immunoassay analysis may be possible and can be a cost-effective method for monitoring, depending on the analytical goals and the number of samples. To save money, several golf courses could pool resources and share immunoassay analyzer equipment and kits. See the "Irrigation" chapter of this document for more information on irrigation-related water quality issues.

6.4 Interpreting Water Quality Testing Results

Interpretation and use of water quality monitoring data depend to a large extent on the goal of the monitoring program. For example, the results may be analyzed to compare:

- values over time
- values following implementation of BMPs, such as IPM measures
- monitoring points entering the site and leaving the site

6.5 Water Quality Monitoring Best Management Practices

Water Quality Monitoring Program Best Management Practices

- ❖ Review existing sources of groundwater and surface water quality information.
- ❖ Develop a water quality monitoring program.

- Establish baseline quality levels for water.
- Identify appropriate sampling locations and sample at the same locations in the future.
- Visually monitor/assess any specific changes of surface waterbodies.
- Follow recommended sample collection and analytical procedures.
- Conduct seasonal water quality sampling, ideally four times per year.

Water Quality Test Result Analysis Best Management Practices

- Compare water quality monitoring results to benchmark quality standards.
- Use corrective measures when necessary.

7 NUTRIENT MANAGEMENT

Elevated levels of nitrogen (N) and phosphorus (P) have been identified as major contributors to the decline of the health of the Chesapeake Bay and the Delaware Inland Bays. Fertilizers containing N and P are a potential source of nutrients that can be transported in leaching and runoff events. Therefore, ensuring that a nutrient management program emphasizes proper fertilization and maintenance of turfgrass on golf courses reduces the potential for N and P losses to groundwater or surface water. The goal of nutrient management programs is to apply the minimum necessary nutrients and maximize their uptake in order to achieve an acceptable playing surface and to maintain turfgrass density.

7.1 Regulatory Considerations

In Delaware, state laws and regulations apply to N and P applications to turfgrass, including golf courses. The Delaware Legislature passed the Delaware Nutrient Management Act (Title 3 Chapter 22 Nutrient Management) in 1999. The purpose of the Delaware Nutrient Management Law is to:

- Establish a certification program that encourages the implementation of best management practices in the generation, handling, and land application of nutrients.
- Formulate nutrient management programs that maintain agricultural profitability and improve water quality.
- Establish a nutrient management planning program.
- Regulate those activities involving the generation and application of nutrients.

7.1.1 Delaware Nutrient Management Certification

As per the Nutrient Management Certification Regulations, golf courses with 10 or more acres of fertilized land must have an employee certified as a private nutrient handler. Initial certification sessions for turfgrass nutrient management are offered annually (in early winter) by the University of Delaware Cooperative Extension Nutrient Management Program. Initial certification for private nutrient handlers is valid for three years. Certified private nutrient handlers must obtain six continuing education units (CEUs) every three years to maintain their Delaware Nutrient Management Certification. (One CEU = 50 minutes of instruction.)

Large facilities may be able to offer their own training to satisfy the CEU requirement; the University of Delaware Nutrient Management Program should be consulted to be approved for CEU credits. Please note that certification follows the individual and not the facility. If a facility's certified private nutrient handler leaves, another individual must become certified.

7.1.2 Nutrient Management Planning

All Delaware golf courses with 10 or more acres of fertilized land must have a valid nutrient management plan or a nutrient management general permit.

Nutrient Management Plans

Only a certified nutrient consultant can write a nutrient management plan for a Delaware golf course. DDA maintains a list of public and private consultants who are certified to write nutrient management plans for Delaware operations. Cost-share funds are available through the DDA to offset the costs of obtaining a nutrient management plan. Contact the DDA Nutrient Management Program for more information.

Nutrient management plans are valid for three years. Updates to a nutrient management plan must be completed by a certified nutrient consultant at least every three years, upon significant changes to the operation activities, or when there is an increase in operations of 25% or more. The Delaware Nutrient Management Commission should be informed of plan updates no later than December 15 of the year in which it must be updated.

Nutrients applied to land managed under a nutrient management plan must be handled in accordance with the operation's approved nutrient management plan and done by or supervised by an individual who is certified by the Delaware Nutrient Management Program. The following standards apply to all nutrient management applications in Delaware:

- Fertilizer applications are prohibited between December 7 and February 15 or to frozen or snow-covered ground.
- Fertilizer applications to impervious surfaces (roads, sidewalks, and other paved surfaces) must be removed on the same day.
- Annual applications of P to soils that exceed 150 UD-FIV (University of Delaware Fertility Index Value = 150 mg/kg Mehlich 3 P) cannot exceed 1 lb P_2O_5 per 1000 ft^2 or a three-year plant removal rate justified by a certified nutrient consultant.
- Soil sampling and testing must be completed every three years.
- Recordkeeping
    - Soil test results and nutrient application rate recommendations.
    - A copy of the applicable nutrient management plan or nutrient management general permit.
    - A log indicating the source (including analyses), rate, dates, and method of application for nutrients (N and P).
- Annual reporting by March 1 every calendar year is required. (DDA provides the form.)

Nutrient Management General Permits

Golf courses may be eligible for a nutrient management general permit, provided they meet the following requirements:

- Land was planted in perennial crops or turfgrass for a minimum of two years.

- A nutrient management plan was implemented for a minimum of three years.

The nutrient management general permit is intended as a substitute for the nutrient management plan specifically for low-risk operations. Golf courses with an approved nutrient management plan in place for a period of three or more years that are interested in applying for coverage under the nutrient management general permit should file a notice of intent (NOI) for coverage with the Delaware Nutrient Management Commission. Upon approval by the Delaware Nutrient Management Commission, golf courses managed under a nutrient management general permit must meet the record keeping and annual report requirements outlined above for the nutrient management plan.

Applications of N and P are managed more strictly under the nutrient management general permit than under a nutrient management plan. Nutrients applied to land managed under a nutrient management general permit must be handled according to the following standards:

- Soil sampling of fertilized areas must be conducted once every three years (at a minimum).
- Fertilizer applications are prohibited within 10 feet of the vegetative edge of any stream, pond, lake, river, drainage conveyance, or stormwater management facility.
- Fertilizer applications are prohibited between December 7 and February 15 or to frozen or snow-covered ground.
- Application of raw animal manure is prohibited.

<u>Phosphorus</u>

- Annual applications of P cannot exceed 2 lb P_2O_5 per 1,000 ft^2 (87 pounds per acre) per year unless justified in writing by a certified nutrient consultant.
- Annual applications of P to soils with phosphorus concentrations greater than 150 UD-FIV may not exceed 1 lb P_2O_5 per 1,000 ft^2.

<u>Nitrogen</u>

- Single applications of fertilizers containing >70% of N in a water-soluble form should not exceed 1 lb N per 1,000 ft^2.
- Single applications of fertilizers that contain at least 30% of the total N in a slow release form (water insoluble N) should not exceed 2 lb N per 1,000 ft^2.
- Single applications of soluble N sources should not exceed 1 lb per 1,000 ft^2.
- Annual N recommendations presented in Table 3 are acceptable under the general permit with written approval of a certified nutrient consultant.
- Annual N applications may not exceed 2 lb N per 1,000 ft^2 for standard maintenance and 3 lb N per 1,000 ft^2 for high maintenance areas without written approval of a certified nutrient consultant.

Table 3. Annual N regulatory limits for the turf general permit for common turfgrass species grown in Delaware based on maintenance level.

Turfgrass Species	Annual Nitrogen Rate (lb/1000 ft^2)	
	Standard Maintenance	High Maintenance
Cool Season		
Creeping Bentgrass	3	4-5
Perennial Ryegrass	2	4-5
Kentucky Bluegrass	2	4-5
Poa Annua	3-4	5-6
Tall Fescue	2	3-4
Fine Fescue (K-31)	2	3-4
Warm Season		
Bermudagrass	3-4	4-6
Zoysia grass	2-3	4-5

The maintenance level of a turf area is dependent on several factors that demand more nutrients, namely N. High and standard maintenance must be determined by each area and should represent management intensity to include mowing, travel, stress levels, compaction, pest pressure, irrigation, and other management factors, as appropriate.

High maintenance turf includes areas with:

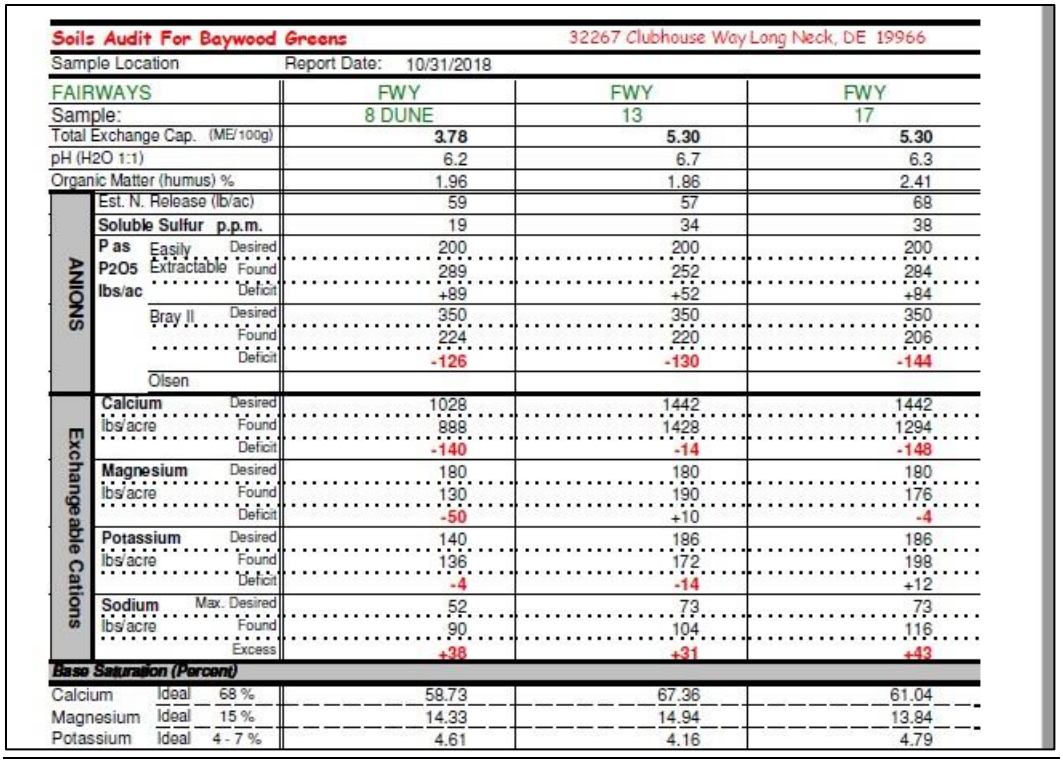
- Frequent mowing (3 or more times per week) to a low height (≤0.75 inches) with removal of grass clippings.
- Irrigated turf.
- Vehicle or personnel traffic that creates visual damage to the turf area.
- Insect pest pressure or disease pressure that demonstrates visual plant damage and stress.
- A sandy growth medium for improved drainage, such as California greens.

Standard maintenance turf includes areas with:

- Limited traffic.
- Grass clippings recycled.
- Native healthy soil structure.

7.2 Soil Testing

Soil testing provides the basis for sound nutrient management and water quality protection programs in golf turf management, especially given the dynamic nature of the sandy soils of many putting greens and tees (Figure 16). In Delaware, golf courses are required to have soils tests at least every three years and maintain records of the results in accordance with the nutrient management plan or general permit. The DDA maintains a list of soil test laboratories. Using the same soil testing laboratory for subsequent soil tests allows for easy comparisons of changes in soil fertility values over time. Keeping soil test results from prior years also allows monitoring changes in soil nutrient levels over time and provides evidence of the impact of nutrient management plans.



Soils Audit For Baywood Greens — 32267 Clubhouse Way Long Neck, DE 19966

Sample Location — Report Date: 10/31/2018

			FWY	FWY	FWY
FAIRWAYS					
Sample:			8 DUNE	13	17
Total Exchange Cap. (ME/100g)			**3.78**	**5.30**	**5.30**
pH (H2O 1:1)			6.2	6.7	6.3
Organic Matter (humus) %			1.96	1.86	2.41
ANIONS	Est. N. Release (lb/ac)		59	57	68
	Soluble Sulfur p.p.m.		19	34	38
	P as P2O5 lbs/ac	Easily Extractable Desired	200	200	200
		Found	289	252	284
		Deficit	+89	+52	+84
		Bray II Desired	350	350	350
		Found	224	220	206
		Deficit	-126	-130	-144
		Olsen			
Exchangeable Cations	**Calcium**	Desired	1028	1442	1442
	lbs/acre	Found	888	1428	1294
		Deficit	-140	-14	-148
	Magnesium	Desired	180	180	180
	lbs/acre	Found	130	190	176
		Deficit	-50	+10	-4
	Potassium	Desired	140	186	186
	lbs/acre	Found	136	172	198
		Deficit	-4	-14	+12
	Sodium	Max. Desired	52	73	73
	lbs/acre	Found	90	104	116
		Excess	+38	+31	+43
Base Saturation (Percent)					
Calcium	Ideal 68 %		58.73	67.36	61.04
Magnesium	Ideal 15 %		14.33	14.94	13.84
Potassium	Ideal 4 - 7 %		4.61	4.16	4.79

Figure 16. Soil test results provides the basis for sound nutrient management and water quality protection programs in golf turf management.

A standard soil test provides information on soil pH and the levels of the macronutrients phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) and often contains concentrations of typical micronutrients iron (Fe), zinc (Zn), copper (Cu), or boron (B). Soil test results do not provide soil N concentrations because N constantly fluctuates between plant available and unavailable forms. However, soil test results typically provide a recommendation for N levels and timing of applications. It is important to note that different soil testing laboratories offer different tests as part of their "routine" packages. For example, the University of Delaware Soil Testing Program offers the pH test, the lime requirement test, and the Mehlich 3 soil test for P, K, Ca, Mg, B, Cu, and Mn as part of the routine analysis.

Soil testing labs report extractable macronutrient and micronutrient concentrations using a variety of units, including parts per million (ppm), pounds per acre (lb/A), or as a fertility index value (FIV). The University of Delaware Soil Testing Program uses the Mehlich 3 soil test method for routine fertility testing and reports soil test results for macronutrients as the FIV. Micronutrients (B, Mn, and Zn) and S (as SO_4^{2-}) are reported in lb/A by the University of Delaware Soil Testing Program. The University of Delaware uses four soil test categories to rate soils in terms of the likelihood of a probable plant response to P, K, Ca, and Mg additions in fertilizers. General interpretations are assigned to each soil test category as follows:

> *Low (0-25 FIV).* The nutrient concentration in the soil is inadequate for the growth of most plants and will very likely limit plant growth. There is a high probability of a favorable response to additions of a nutrient.

Medium (26-50 FIV). The nutrient concentration in the soil may be adequate for plant growth but should be increased into the optimum range to ensure that plant growth is not limited. There is a low to moderate probability of a favorable response to additions of a nutrient.

Optimum (51-100 FIV). The nutrient concentration in the soil is in the range recommended for the growth of all plants. Since there is a very low probability of a favorable response, nutrient additions are rarely recommended.

Excessive (>100 FIV). The nutrient concentration in the soil is above the range recommended for the growth of all plants. Additions of the nutrient are not recommended. Erosion, runoff, and leaching from soils that are excessive in P can have negative effects on water quality.

Soil test reports usually recommend nutrient (including N) and lime application rates, as well as frequency of application. The results form the basis for nutrient management planning for the selection of nutrient sources, rates of application, and appropriate timing to meet site specific needs for greens, tees, fairways, and roughs.

For more information on soil testing, see the following publications:

- Soil Sampling and Analysis, Delaware Nutrient Management Program.
- How to Take a Soil Sample, University of Delaware.
- Recommended Soil Testing Procedures for the Northeastern United States. University of Delaware Extension.
- Interpreting Soil Phosphorus and Potassium Tests, University of Delaware Extension.

7.3 Plant Tissue Analysis

Plant tissue analysis can provide additional information on the nutritional status of a turfgrass stand when used in conjunction with soil testing. While soil test results provide an index of potentially plant available essential nutrients in the soil, they do not indicate how much of any given nutrient that the plant has taken up. Analysis of turfgrass tissue samples indicates the level of macronutrients and micronutrients in the plant. However, low concentrations of a given plant nutrient in tissue may not indicate a lack of nutrient availability but rather of an abiotic problem (such as drought stress or herbicide damage) or a biotic problem (such as an insect or disease issue) that reduces or inhibits nutrient uptake. A lack of regional correlation data and numerous problems regarding taking representative tissue samples further limit the impact of using tissue sampling as the primary tool for adjusting nutrient management programs.

Perhaps the greatest potential use of tissue sampling is for turf grown on soil with a very low cation exchange capacity (CEC), such as the high sand content mixtures used on greens and tees. In these situations, the nutrient retentive capacity of the soil is very low, and the potential for nutrient imbalances (high levels of one nutrient causing excessively low levels of another nutrient) in the plant is thus relatively high. Tissue sampling can indicate when such imbalances

are occurring. These situations are most likely to be occur with micronutrients but can also occasionally occur with macronutrients. For more information on collecting plant tissue samples and interpreting the results, see *Plant Analysis: An Important Tool in Turf Production*.

7.4 Fertilizers

In Delaware, the DDA Agricultural Compliance Laboratory analyzes samples of fertilizer and agricultural lime sources to ensure that labeling guarantees are met and that the product is safe for the environment. A fertilizer label must contain the following five components:

- brand
- grade
- guaranteed analysis
- net weight
- name and address of the registrant and licensee

Fertilizers are also often classified as either organic (containing carbon) or inorganic (containing no carbon). Organic fertilizer sources can be a naturally occurring animal or plant byproducts or a synthetic product such as urea or any urea-based compound (ureaformaldehyde, methylene urea, isobutyraldehyde urea, etc.). However, "organic fertilizer programs" are likely using naturally occurring organic sources and not synthetics.

The grade (19-19-19) and the guaranteed analysis are typically most important for fertilizer selection. The grade presents the percentages by weight of N, phosphate (P_2O_5), and potash (K_2O). Note that the grade is not N, P, and K; the percentages of the actual (or elemental) P and K nutrients can be determined by multiplying the P_2O_5 level by a constant of 0.44 and the K_2O level by 0.83. While most soil test recommendations for these nutrients are provided in units of P_2O_5 and K_2O per 1,000 ft^2, concentrations are sometimes provided in pounds of the actual nutrient instead. The guaranteed analysis details all nutrients in the product (in addition to N, P_2O_5, and K_2O) on a percent by weight basis.

Complete fertilizers contain N, P_2O_5, and K_2O, while incomplete fertilizers contain only one or two specific nutrient needs (such as 45-0-0, 0-20-0, 0-0-50, 18-46-0). Balanced fertilizers contain equal amounts of N, P_2O_5, and K_2O (e.g., 8-8-8, 10-10-10, or 19-19-19, etc.). Balanced fertilizers are often referred to as "garden fertilizers" because of their use in gardening applications to optimize bloom or fruit yield with phosphate and potassium. The widescale use of balanced fertilizers is often discouraged because of the emphasis placed on applying P only when indicated by a soil test. Unbalanced fertilizers have varying levels of nutrients (such as 29-3-7, common in many turf-specific products).

7.5 Nitrogen

Nitrogen applications to golf course turf are essential to provide sufficient growth to recover from intense traffic, to minimize the potential for disease incidence, and to maintain sufficient turfgrass density that minimizes weed encroachment, surface water runoff, and soil erosion.

Three areas of N applications that are interrelated need to be addressed to develop a sound N management program:

- Source of N in a fertilizer.
- Rates of application (per application and total annual N applied).
- Timing of applications during the year.

A wide range of N-containing fertilizers is available to the turfgrass manager. These fertilizers generally fall into one of two broad categories:

- Fertilizers that contain only soluble, quickly available N.
- Fertilizers that contain some N in a slow release form that is not immediately available for plant use.

7.5.1 Water Soluble Nitrogen

Fertilizers with N that can immediately go into solution, and thus have N that is rapidly available for turf uptake, are categorized as water soluble N fertilizers. These fertilizers, while quickly available for turf use, have the most potential for leaching if used improperly.

The most common water soluble forms used for golf course fertilization contain N in the ammonium form (NH^{+4}). Soluble N fertilizers that contain ammonium N include urea, ammonium sulfate, and ammonium chloride. These fertilizers can produce excellent quality turf without leaching or runoff problems if used properly. The ammonium N can be absorbed by the soil, reducing the potential for N movement. Ammonium sulfate can be particularly useful in suppressing diseases, such as take-all patch in young bentgrass, and other common patch diseases of turfgrass, such as spring dead spot in bermudagrass.

Some water soluble N fertilizers contain N in the nitrate (NO_3) form. N leaching and runoff potential is much higher for NO_3-N than other forms of N. Thus, where conditions exist that are conducive to leaching or runoff, fertilizers that contain significant amounts of NO_3-N should not be used. These conditions include sandy sites (sands and loamy sands) with high water tables, times when turf is not actively growing, and sites that are highly sloped. Fertilizers high in NO_3-N include ammonium nitrate, potassium nitrate, and calcium nitrate. Fertilizers that contain predominantly NO_3-N should only be used on sites not prone to runoff or leaching, where very rapid response is essential, and on turf that is actively growing. Turfgrass uptake may occur within a few days with NO_3-N containing fertilizers compared with seven to 10 days with NH_4-N fertilizers. Generally, fertilizers containing significant amounts of NO_3-N are not recommended for turfgrass fertilization.

Excessive rates of soluble N per application can result in excessive growth of turf (which can eventually affect tolerance to environmental stress and pest resistance) and can increase the potential for N loss through leaching, particularly on sandy soils.

7.5.2 Enhanced Efficiency Nitrogen

Enhanced efficiency fertilizers allow increased nutrient availability and reduce potential of nutrient losses to the environment (e.g. leaching, runoff, gasesous losses) when compared to an appropriate reference product, such as the soluble fertilizers urea or ammonium sulfate. Enhanced efficiency fertilizers are divided into two groups: stabilized fertilizers and slow-release fertilizers.

Stabilized Fertilizers

Stabilized fertilizers reduce nitrogen loss in its gaseous form via one of two processes – nitrification and ammonia volatilization. Nitrification occurs mostly in areas with high organic matter, high moisture, low oxygen concentrations and slightly acidic to basic soil pHs. Increasing temperatures also increase the rates rate of nitrification. Stabilized fertilizers with nitrification inhibitors reduce the amount of nitrogen converted to nitrate after application.

Ammonia volatilization may occur when ammonium-based fertilizers are applied to calcareous soils but more commonly the transformation of nitrogen to ammonia is accomplished by microorganisms. Factors that affect microbial growth and metabolism of these microorganisms will affect the rate of volatilization. These factors include the amount of urea or ammonium, temperature, pH and moisture affect the rate at which volatilization occur. Increasing temperatures can lead to volatilization. Stabilized fertilizers with chemical additives called urease inhibitors can reduce this volatilization potential and promote nitrogen uptake.

For more information, see the article "Enhanced Efficiency Nitrogen Fertilizers".

Slow-release Fertilizers

Slow release N fertilizers contain N in a form that delays its availability for plant uptake after application, extending N availability significantly longer than a rapidly available nutrient source such as urea. Slow release N fertilizers include sulfur coated urea (SCU), polymer coated ureas, ureaformaldehyde (UF), methylene ureas, isobutylidene diurea (IBDU), and natural organics.

While varying considerably in individual characteristics and release patterns, slow release N fertilizers typically provide more even turfgrass response and uptake over a longer period of time. The use of slow release fertilizers should particularly be considered on sites that are prone to leaching, as recent studies show that under certain conditions some slow-release nitrogen fertilizers are less likely to leach into groundwater than soluble fertilizers.

Natural organic fertilizers are slow release N fertilizers that are derived from either a plant or animal product and do not contain synthetic materials. They have not been altered from their original state except by physical manipulation (drying, cooking, chopping, grinding, shredding, or pelleting). Most natural organic fertilizers contain P and thus have additional regulations imposed on their application.

7.6 Nitrogen Rates and Timing

7.6.1 Turfgrass Establishment

For establishment of turfgrass on sand-based soils (both natural and modified), the University of Delaware recommends the use of enhanced efficiency fertilizers, preferably products with 50% or more slowly available N sources. Apply 1 lb N per 1000 ft^2 at planting using products containing >50% slowly available N to feed the plants for the first four weeks. Warm season grasses should receive additional applications of readily-available N sources at a rate of 0.25 to 0.5 lb N per 1000 ft^2 per week for the next four weeks. Fertilize cool-season grasses for the next eight weeks with 0.25 lb N per 1000 ft^2 if using fertilizers with <50% slowly available N or 0.5 lb N per 1000 ft^2 if using fertilizers with >50% slowly available N.

For establishment of turfgrass on heavier soils (predominantly silt or clay), apply up to 1 lb N per 1000 ft^2 of a fertilizer containing >50% slowly available N to feed warm- or cool-season turf for up to four weeks. If readily-available sources of N are used, split the total N application into four weekly applications of 0.25 lb N per 1000 ft^2. Follow the initial N application with weekly applications of readily-available N sources at a rate of 0.25 to 0.5 lb per 1000 ft^2.

7.6.2 Turfgrass Maintenance

In Delaware, N applications are regulated as part of a nutrient management plan or general permit, as discussed in the Regulatory Considerations section of this chapter. Nitrogen applications must be handled in accordance with the operation's approved nutrient management plan or in compliance with N rate (Table 3) and timing guidelines of the nutrient management general permit (as applicable). Applications of N fertilizer are prohibited between December 7 and February 15 and to snow-covered or frozen ground outside of this date range for all Delaware golf courses.

7.7 Nitrogen Applications

When possible, maintenance N applications should be split into two or more applications. This strategy meets both turfgrass nutritional needs and minimizes potential water quality concerns. Restricting N application levels is especially important on sand-based putting greens and is easily adapted into green management programs, where it is commonplace for superintendents to "spoonfeed" (0.05 to 0.4 lb N per 1,000 ft^2) the turf, making numerous light applications of nutrients on a frequent basis. This strategy balances turfgrass growth and color with requirements for turf health, recovery, and playability, in addition to reducing nutrient leaching potential.

Spoonfeeding can be accomplished with both granular and liquid applications. The practice of liquid feeding or foliar feeding is popular for facilities with spraying equipment. Liquid feeding uses greater than 45 gal/A (1 gal per 1000 ft^2) of water, and most nutrient uptake occurs through

the root system. Foliar feeding uses less than 45 gal/A water carrier to keep most of the nutrients on the leaf surface for foliar absorption.

Applying fertilizer in water improves the uniformity of distribution and allows small amounts of nutrients to be accurately applied with water as the carrier. Fertigation (delivery through an irrigation system) is another specialized means of delivering nutrients and is especially effective during a grow-in when wet soils are not conducive to spreader and/or sprayer operation. Fertigation performance is only as good as the distribution and uniformity capabilities of the irrigation system. Dispersible granule fertilizer formulations are now available that provide enhanced turf coverage that mimics foliar or liquid feeding. Upon contact with water, a single fertilizer granule separates into several thousand particles, thus coating the turfgrass foliage. This formulation technology is expected to become more widespread.

7.8 Phosphorus

Phosphorus is a critical nutrient for turfgrass growth and development, playing important roles in energy transformations in plant cells and root development. Phosphorus is particularly critical for new sites being established from seed**.** On the fertilizer label, the middle number of the analysis represents the percent by weight of P_2O_5, which can be converted to % P by multiplying by 0.44 (10-10-10 is actually 4.4% by weight P).

In anionic form (HPO_4^{2-} or $H_2PO_4^-$), P is highly leachable and is a concern for water quality. However, the complexing of P with other elements (such as aluminum, iron, or calcium) greatly minimizes P leaching in native soils, unless P has been overapplied for many seasons. Phosphates are a potential leaching concern during the grow-in of turfgrasses on sand-based systems that inherently have very low nutrient holding capacity and are subject to frequent irrigation. On sand-based soils, P leaching can also be a concern if over-applied. Therefore, phosphorus should only be applied to established turf when a routine soil test shows need. The application of fertilizers near water resources and/or hardscapes that move stormwater is prohibited under a general nutrient permit.

7.8.1 Phosphorus Rates and Timing

Phosphorus is particularly critical for establishing new stands of turf. Established turf, however, can generally tolerate relatively low levels of soil P. Phosphorus applications are regulated under Delaware law and should be based on results of a soil test. Areas on the golf course that will be fertilized with P must be sampled and tested every three years. Soil testing is recommended on an annual basis for greens and tees, especially in sand-based systems, due to the potential for rapid depletion of soil P due to high maintenance. The University of Delaware's recommended rates for P applications based on soil tests are shown in Table 4.

Table 4. University of Delaware P application recommendations for golf turf.

Application Timing and Method	Soil Test Phosphorus Category			
	Low[1] (0-25 FIV)	**Medium (26-50 FIV)**	**High (51-100 FIV)**	**Excessive (>100 FIV)**
	Pounds P^2O^5 per 1,000 ft^2			
Establishment				
Broadcast[2]	2 – 3	1 – 2	0 – 1	0
Incorporated[3]	3 – 4	1 – 2	0 – 0.5	0
Maintenance	2 – 3	1 – 2	0 – 0.5[4]	0

[1]Facilities managed under a Delaware Nutrient Management General Permit are prohibited from applying P at a rate >2 lb P_2O_5 per 1000 ft^2. Higher rates are restricted to those facilities managed under a nutrient management plan with written justification by a certified nutrient consultant.

[2]Surface broadcast or incorporated into soil to a depth <2 inches.
[3]Incorporated into soil to a depth >2 inches depth.

[4]Maintenance applications of P to soils testing in the high category are recommended only to encourage recovery in situations where turfgrass has been severely damaged.

7.8.2 Phosphorus Applications

For facilities managed under a nutrient management general permit, annual applications of P to established turf cannot exceed 2 lb P_2O_5 per 1,000 ft^2 (87 pounds per acre) per year unless justified in writing by a certified nutrient consultant. Annual applications of P to soils with phosphorus concentrations greater than 150 UD-FIV may not exceed 1 lb P_2O_5 per 1,000 ft^2. For golf courses under a nutrient management plan, annual applications of P to established turf growing soils that exceed 150 UD-FIV cannot exceed 1 lb P_2O_5 per 1000 ft^2 or a three-year plant removal rate justified by a certified nutrient consultant. However, researchers have shown little benefit to applications of P to soils where soil test P concentrations are above the agronomic optimum, even for overseeding, spot renovations, or sodding.

Applications of P fertilizer are prohibited between December 7 and February 15 and to snow-covered or frozen ground outside of this date range for all Delaware golf courses.

7.9 Potassium

Potassium is not a direct component of any organic compound within a plant but is heavily involved in many biochemical responses. K is the nutrient that most impacts water relations within the plant, sometimes referred to as the "antifreeze" and "coolant" nutrient of the plant world. Potassium is generally more critical for established turf and may play a role in drought, heat, cold, and wear tolerance. Potassium is not considered to be an environmental concern that negatively impacts water quality and therefore does not receive the regulatory attention that N and P do.

The University of Delaware provides K recommendations for establishment and maintenance. However, K applications are generally more critical for established turf. While soil tests should be taken routinely to monitor soil K levels, experience has shown that K fertilizer rates that are approximately half that of the annual N fertilizer rate are generally sufficient to maintain

adequate soil K levels. Recommended rates for soil test-based K applications are shown in Table 5.

Table 5. University of Delaware K application recommendations for golf turf.

Application Timing and Method	Soil Test Potassium Category			
	Low (0-25 FIV)	Medium (26-50 FIV)	High (51-100 FIV)	Excessive (>100 FIV)
	lb K^2O per 1,000 ft^2			
Establishment				
Broadcast[1]	2 – 3	1 – 2	0 – 2	0
Incorporated[2]	3 – 5	1 – 2	0 – 2	0
Maintenance				
Broadcast	2 – 4	1 – 3	0 – 2	0

[1]Surface broadcast or incorporated into soil to a depth <2 inches.
[2]Incorporated into soil to a depth >2 inches depth.

7.10 Secondary Macronutrients

Secondary macronutrients are essential to plant function and are required in quantities less than N, P, and K, but more than micronutrients. These include Ca, Mg, and S. Each are described briefly below:

- *Calcium*: Primarily a component of cell walls and structure. Found in gypsum, limestone, and calcium chloride.
- *Magnesium*: Central ion in the chlorophyll molecule and chlorophyll synthesis. Found in S-Po-Mg, dolomitic limestone, and magnesium sulfate.
- *Sulfur*: Metabolized into the amino acid cysteine, which is used in various proteins and enzymes. Found in ammonium sulfate, elemental sulfur, gypsum, and potassium sulfate.

7.11 Micronutrients

Understanding the role of each micronutrient within the plant should provide a greater understanding of the key role these nutrients play in proper turfgrass management. Micronutrients are just as essential for proper turfgrass health as macronutrients but are required in very small quantities compared with macronutrients. Micronutrients include FE, Mn, B, Cu, Zn, Mo and Cl.

- *Iron*: Part of the catalytic enzymes, Fe is required for chlorophyll synthesis affecting photosynthesis, nitrogen fixation, and respiration. Delaware soils contain a fair amount of Fe. However, because it complexes with other nutrients in the soil, Fe is the micronutrient most likely to be deficient. Iron occurs primarily as oxides and hydroxides that are sparingly soluble in well-aerated soils above pH 4.0. Root exudates of organic acids from deeply rooted plants are generally able to solubilize sufficient iron to optimize plant growth, but high N rates and close mowing decrease root growth relative to shoot growth and limit uptake capability. The inherently low levels of Fe in high-sand putting green soils, and some of the native sandy sands, along with the relatively high supply of

N and P in these management systems can further complicate Fe uptake.

- *Manganese*: Involved in photosynthesis, Mn is required as a cofactor for about 35 enzymes. Lignin biosynthesis depends on Mn.

- *Boron*: Found in the cell wall. B is probably required for the structural integrity of the cell wall.

- *Copper*: Cu-protein plastocyanin is involved in photosynthesis and is a cofactor for a variety of oxidative enzymes.

- *Zinc*: Zn is a structural component of enzymes and is required for protein synthesis. Carbohydrate metabolism is affected by Zn.

- *Molybdenum*: Mo is primarily related to nitrogen metabolism and is involved in the structural and catalytical functions of enzymes.

- *Chlorine*: Cl is required for the oxygen-evolving reactions of photosynthesis and appears to be required for cell division in both leaves and shoots.

To correct Fe deficiency, apply ferrous sulfate or iron chelate at a rate of 0.5 ounces Fe per 1,000 ft^2. Iron applications should be avoided during the heat of the day. Applications can be made three to four times in summer and/or fall. Repeated applications may be needed to prevent reoccurrence of Fe deficiencies. Foliar applications of Fe are not recommended between March and June. Granular Fe applications generally do not provide as rapid color responses as foliar applications due to the rapid complexing of the Fe in the soil. As such, soil applications of granular materials are not recommended.

Deficiencies of other micronutrients are rare except on mostly sand soils. Again, maintaining appropriate soil pH ensures satisfactory availability and prevents potential phytotoxicity issues. Some notable Zn and Mn toxicity issues on golf greens have occurred over the years where a popular fungicide (mancozeb) has been repeatedly applied for disease and algae suppression. Zn and Mn solubility can become so high at low soil pH relative to other nutrients that turf phytotoxicity occurs. Maintaining the pH at an appropriate level by application of a soil test-recommended lime application is the easiest way to manage this problem. Where supplemental micronutrient applications are needed (most often indicated by tissue testing), chelated micronutrient formulations are very effective.

7.12 Soil pH

Maintaining soil pH in an optimum range is important for maximizing the efficiency of nutrient use and can be important in reducing weed and disease problems. Turfgrass can withstand a rather broad range of soil pH, but 6.5 is generally considered the target pH for golf turf in Delaware. Wide deviations from this target pH can result in reduced P and micronutrient availability and can interfere with soil N metabolism and availability. Depending on turfgrass

species, problems may start to occur when soil pH is below 5.4 or above 7.8. Soil testing for pH is recommended to maximize efficiency of nutrient availability.

Most of the native soils of Delaware are slightly to moderately acidic. The use of acid-forming fertilizers can further decrease soil pH. Therefore, Delaware soils typically require periodic liming to make the rooting environment hospitable for root exploration and development.

Golf turf soils are rarely too alkaline in the Mid-Atlantic. If soil pH is too high, nutrient deficiencies and toxicities are just as prevalent as for low pH soils. High alkalinity is typically due to excessive lime applications made without soil test recommendations. This situation should be avoided due to the difficulty of managing high pH soils as compared with low pH soils.

7.12.1 Liming Rates

The University of Delaware makes recommendations for limestone applications to achieve a soil pH of 6.5 based on the results of a routine soil test (which includes the soil pH and lime requirement tests). Lime recommendations are based on the use of pure $CaCO_3$, use Calcium Carbonate Equivalence (CCE) values to calculate an equivalent rate of liming material if calcitic lime is not used as the liming material. See the fact sheet Liming Materials for more information on calculating CCE values.

Whenever possible, soil pH should be adjusted prior to establishment as pre-plant incorporation greatly accelerates the neutralization of the acidity throughout the root zone. In addition, applying limestone approximately one month or more before seeding can minimize potential P availability problems and the potential for volatilization loss of applied N. When liming established turf, no more than 50 pounds of lime per 1,000 ft^2 is recommended in a single application and 25 pounds per 1,000 ft^2 application to golf putting greens**.** If recommended rates exceed these thresholds, then the total amount of lime should be split into two or three treatments that are applied two to four months apart until the whole amount of lime is applied.

The beneficial effects of liming occur only where lime and soil are in contact. Traditional liming materials applied to mature turf stands are sparingly soluble and react strongly with the soils that they contact. As a result, most lime materials are relatively immobile in the soil and surface applications generally affect no more than the surface two to three inches during a growing season. To move more lime into the soil profile, lime can be applied in conjunction with hollow-tine core aerification events. Lime is typically applied during the active growing season when the turf can quickly rebound from the damage/surface disruption of the coring. Applying lime in the fall and winter months is also possible because the foliar burn (leaf desiccation) potential from the liming material is very low, and the freezing and thawing of the soil over winter can aid in mixing lime throughout the root zone.

While these recommendations should result in satisfactory establishment in most situations, many factors can impact whether modifications of these recommendations are warranted for a specific site. For example, it may be desirable to maintain a lower soil pH (5.4 to 5.7) if diseases

such as take-all patch of bentgrass, summer patch of Kentucky bluegrass, or spring dead spot of bermudagrass are of concern.

7.12.2 Soil Acidification

Turfgrass areas with excessively high pH can be amended gradually over time through the application of acid- forming N fertilizers such as ammonium sulfate. Where pH is so high it requires immediate attention, the chemical amendments of choice are elemental sulfur or aluminum sulfate. Depending on the source used, maximum application levels are quite restricted due to the caustic nature of these materials (no more than 5 lbs per 1,000 ft^2 in a single application). Like liming recommendations, adjustments to lower soil pH should only be based on a soil test.

7.13 Fertilizer Equipment Selection and Maintenance

Different types of spreaders are available, and advantages and disadvantages exist for each. In addition, not all fertilizers can be spread with every spreader. For example, a drop spreader can damage the sulfur coating in sulfur-coated urea, essentially leading to an increase of soluble urea. It is important that you use the appropriate type of applicator or spreader for the fertilizer.

Most importantly, accurately calibrated sprayers or spreaders are essential for proper application of fertilizers. Incorrectly calibrated equipment can easily apply too little or too much fertilizer, resulting in damaged turf, excess cost, and greater potential of nutrient movement off-site. An excellent resource for spreader care and calibration can be found at Penn State's Department of Plant Science. Spreaders should also be thoroughly cleaned after use due to the high salt content that corrodes metal parts and in keeping with the BMPs for equipment washing as discussed in the "Maintenance Operations" chapter of this document.

7.14 Nutrient Management Best Management Practices

Nutrient Management Planning Best Management Practices

- Follow the nutrient management plan or general nutrient management plan fertilizer application rates.

Soil Testing Best Management Practices

- Divide the course into logical components such as greens, fairways, tees, and roughs. In addition, do not combine samples from areas that have different past management histories, exhibit different problems, or have different turfgrass species.
- Ten to 15 soil samples should be randomly taken from each sample area and blended together to provide a representative, uniform soil sample.
- Each soil sample should be taken from the same depth, with thatch removed.
- Use the same soil testing laboratory for subsequent soil tests to compare changes in soil fertility values over time.

Fertilizer Applications Best Management Practices

- Licensed nutrient applicators should apply nutrients or directly supervise nutrient applications by experienced or trained staff.
- Prevent fertilizers from being deposited onto impervious surfaces.
- Avoid applying fertilizer to soil at or near field capacity or following rain events that leave the soil wet.
- Do not apply fertilizer when heavy rains are likely.
- Maintain buffer areas around waterbodies that are not fertilized.
- Choose the appropriate type of spreader for a given fertilizer.
- Identify those areas on the golf course most prone to potential losses or potential impacts on water quality.
- On highly sloped areas, use slow release N sources and apply a maximum of 0.9 pounds N per 1,000 ft^2 per application and avoid application prior to any expected high rainfall. If suitable for the site, use species such as hard or chewings fescue or other species with lower N requirements.
- Use species with low N requirements in areas immediately adjacent to water.
- On sandy soils in areas with high water tables, use slow release N sources or spoon feed to apply at a maximum rate of 0.9 pounds N per 1,000 ft^2.
- Apply slow release N fertilizers at the appropriate time of year to maximize release characteristics. For example, an application of slow release N to warm-season turfgrass in fall may not be as effective as the same application applied in early summer because of the prolonged release time in fall.
- Do not use fertilizers that contain significant amounts of NO3-N on sites conducive to leaching and runoff, such as sandy sites (sands and loamy sands) with high water tables and highly sloped sites or when turf is not actively growing.
- Irrigate turf after it has been fertilized to bring fertilizer into contact with soil and to move soluble N into the soil. Irrigation intensity must be low enough so that water infiltrates soil instead of contributing to runoff.
- When feasible, leave clippings. This may reduce annual fertilizer N requirements.
- Direct drainage systems from greens, tees, and fairways to areas of lower maintenance, such as non-irrigated roughs.
- Appropriate organic matter should be part of the root zone mixture for putting green construction to increase nutrient retention. (See USGA specifications.)
- Avoid applying fertilizer to soils that are at, or near, field capacity or following rain events that leave the soils wet.
- Do not apply fertilizers within 15 feet of waterways; or within 10 feet if a drop spreader, rotary spreader with deflector, or targeted spray liquid is used.

Soil pH Best Management Practices

- Test soil pH as part of soil testing.
- Adjust soil pH as needed, targeting 6.5 as an ideal pH for Delaware soils.

Fertilizer Equipment Best Management Practices

- Accurately calibrate sprayers or spreaders.
- Thoroughly clean equipment after and in keeping with the BMPs for equipment washing.
- Perform routine maintenance on equipment, such as inspecting hoses, maintaining tire pressure, changing oil, cleaning filters, and replacing old nozzles.

8 CULTURAL PRACTICES

Dense, healthy turf with adequate infiltration plays an important role in preventing runoff and erosion. Cultural practices promote both turf density and health, in balance with providing a high-quality playing surface. These practices include cultivar selection, mowing, aeration, surface cultivation, topdressing, and rolling.

8.1 Cultivar Selection

Site preparation, the choice of cultivar, and correct management practices are essential to establishing and maintaining turfgrass. Delaware is in the transition zone where the cool-season grasses (Kentucky bluegrass, perennial ryegrass, tall fescue, red fescue) are stressed during hot and humid summers, and the warm season grasses (Bermuda grass and zoysia grass) turn brown after a frost and can be invasive. Turf-type tall fescue is well adapted for Delaware and requires less fertilizer than bluegrass and ryegrass.

Numerous new turfgrass cultivars continue to be developed and released by turfgrass breeders. However, many of these cultivars are adapted to the environmental conditions that prevail in other regions of the country and are not adapted to the specific environmental conditions that occur in the transition zone. Thus, to identify cultivars that perform well in this region, extensive cultivar trials are evaluated each year at the University of Delaware and University of Maryland. The cultivar performance data obtained at various trial locations is often reviewed in a joint meeting of university researchers and representatives of the Department of Agriculture of Mid-Atlantic states.

The use of recommended cultivars usually results in a turfgrass stand of higher quality and density, greater stress tolerance, lower nutrient requirements, less water usage, and fewer pest problems. Also, the use of recommended cultivars generally has the benefits of greater water infiltration, reduced need for pesticide applications, reduced water runoff, and the enhancement of the environmental benefits of properly managed turfgrass.

The National Turfgrass Evaluation Program (NTEP) provides information on the testing and adaptation of the turfgrass cultivars, searchable by state and NTEP test location. Delaware will have tall fescue test data beginning in 2019 (Figure 17), but Maryland test results and recommendations can be reviewed and information from eastern Maryland is relevant for Delaware. When selecting cultivars for a specific site, considerations include desired use, site and microclimate conditions, disease resistance, and spring transition traits. For more information, see Recommended Turfgrass Cultivars for Certified Sod Production and Seed Mixtures in Maryland. 2017. University of Maryland.

Figure 17. NTEP trial planted at the University of Delaware in 2018 will provide test data in 2019. Photo Credit: Erik Ervin.

8.2 Mowing

Mowing is the most basic and perhaps the important cultural practice to consider when developing a management plan. Mowing practices impact turf density, texture, color, root development, and wear tolerance. Failure to mow properly results in weakened turf with poor density and quality.

Proper mowing height is a function of the quality of the cut, mowing frequency, the cultivar being managed, and the intended use of the site. Other factors influencing mowing height include mowing frequency, shade, mowing equipment, time of year, root growth, and abiotic and biotic stress. For example, mowing frequency affects turfgrass growth habit. Frequent mowing increases tillering and shoot density, but also decreases root and rhizome growth. Therefore, mowing practices should balance these two physiological responses to enable quick turf recovery through decisions related to height of cut, frequency, and mowing patterns. Mowing too infrequently results in alternating cycles of vegetative growth followed by scalping, which further depletes food reserves of the plants. Proper equipment maintenance is also key to maintaining healthy turf, as sharp mower blades reduce the risk of creating wounds that can favor microbial infection and, in some cases, dissemination of pathogens.

8.2.1 Height of Cut

In general, a taller turf offers a better defense to pests and other stressors, while a closer cut turf is often considered more aesthetically pleasing. Determining the best height of cut (HOC)

requires balancing the stress response to mowing with golfer expectations of playability, staffing levels for mowing frequency, weather conditions, and budget considerations for the increased maintenance and inputs of lower HOCs. Especially at low turf heights (<1.5 inches), the corresponding reduction in root strength requires more intensive maintenance (e.g. water and fertilizers) to maintain turf density.

Ideal tolerance ranges for turf height vary by cultivar. The ideal range maximizes density, though staying within the tolerance range will provide adequate density assuming water, nutrients, etc., are provided optimally. Recommended golf course mowing heights for Mid-Atlantic turf species are found in Tables 6 and 7 below:

Table 6. Recommended minimum golf course mowing heights, by area (in inches).

Turf Species	Greens Healthy Maintenance	Greens Tournament Play	Tees, Collars, Approaches	Fairways
Creeping bentgrass	0.125	0.090	0.250	0.350
Hybrid bermudagrass	0.125	0.100	0.375	0.375
Common bermudagrass	-	-	0.500	0.500
Zoysia grass	-	-	0.400	0.500
Perennial ryegrass	-	-	0.375	0.375
Kentucky bluegrass	-	-	0.500	0.625

Table 7. Recommended mowing heights for roughs (in inches)*.

Kentucky bluegrass	Perennial ryegrass	Tall fescue	Fine fescues	Bermudagrass
1.0 - 6.0	1.0 - 6.0	2.0 - 6.0	2.5 - 6.0	0.75 - 2.50

** For intermediate, primary, and secondary roughs. Intermediate rough cuts are defined as a narrow (<10 feet) step-up cut immediately adjacent to the fairway. HOC for intermediate roughs is usually in the lower part of the specified ranges, typically 1.0 - 1.75 inches.*

Mowing height can also be varied seasonally to improve turf responses to changes in weather and available sunlight such as during spring greenup, summer stress, and cold hardening. For example, in the early spring, warm season grasses have a more prostrate growth habit and can be mowed closer without negatively affecting overall plant health. At this time of year, close mowing can control thatch, increase turf density, remove dead leaf tissue, and promote earlier greenup. In the summer, by contrast, a higher cut helps moderate stress through a variety of means such as insulating the crown from heat stress, reducing weed competition, and reducing water needs.

In shaded areas, shoots elongate to capture sunlight, resulting in a weakened root system. Therefore, the HOC should be raised to increase photosynthetic area and improve carbohydrate availability. Mowing stress can also be reduced by minimizing turning in these areas. In addition,

a plant growth regulator (PGR) can be used as a regular management tool to control growth in shaded environments.

8.2.2 Mowing Frequency

Maintaining an optimal root-to-shoot ratio is critical. Following the traditional rule, mowing should be frequent enough so that no more than one-third of the top growth is removed at any one time. Removing more than 40% of the leaf area inhibits root growth because the grass will use more energy to regenerate new shoots than for sustaining roots. Published recommended mowing frequency during active growth based on various mowing heights is shown in Table 8 (republished with permission from *Environmental Best Management Practices for Virginia's Golf Courses*, Table 7-3, p. 93):

Table 8. Mowing frequency based on various mowing heights.

Mowing height (in inches)	1/3 rule height (in inches)	Frequency
0.12	0.18	Every 1 - 1.5 days
0.25	0.37	Every 2 days
0.5	0.75	Every 2 - 3 days
1.00	1.50	Every 3 - 4 days
1.50	2.25	Every 4 - 5 days
2.00	3.00	Every 5 - 6 days
3.00	4.50	Every 6 - 7 days
4.00	6.00	Every 7 - 8 days

In addition to maintaining an optimal root-to-shoot ratio, mowing should only be performed when field and growing conditions are good. Turfgrass stressed by excessive heat, cold, moisture, drought, traffic, or damage from cultural practices should be mowed at a reduced interval or not mowed at all to aid recovery. When favorable conditions return and if the turf is excessively tall, scalping can be avoided by lowering HOC in small increments so as not to remove more than 30% to 40% of the leaf blade when mowing.

8.2.3 Mowing Patterns

Whenever possible, the direction of cut with mowing equipment should be altered to prevent excessive lateral growth ("legginess") and to maintain the desired HOC. On greens, the direction should be changed every time it is mowed. On most features that are mowed, particularly on fairway-height or lower HOCs, a "clean-up" pass is made around the edge. The frequency with which this area is mowed can often be reduced to alleviate stress, especially in the summer. It may also be necessary to raise the HOC of the clean-up pass at times due to turf loss, thinning, scalping, or other issues negatively impacting the turf.

8.2.4 Mowing Equipment

Several types of mowers are available. Reel mowers are preferred for turf with low HOC (<1.5 inches) because they produce the best quality cut when compared with other types of mowers.

Rotary mowers, when the blades are sharp and properly adjusted, deliver acceptable cutting quality for turf that will be cut above 1 inch in height. Flail mowers are most often used to maintain utility turf areas that are mowed infrequently and do not have a high aesthetic requirement. Mowing equipment should be checked daily after use to ensure the best possible quality of cut. Blades should be sharpened or adjusted as often as necessary to achieve this quality of cut as dull blades can have several undesirable physiological effects, resulting in shredding of leaf tissue, increasing water loss, and boosting the potential for disease.

8.2.5 Clipping Management

Whenever possible, grass clippings should be returned to the grass canopy. Clippings return provides multiple benefits, such as:

- Nutrient recycling of N, P, and K (e.g. up to 1 pound N per 1,000 feet^2 per year) and other essential nutrients.
- Reduced need for supplemental nutrients.
- Elimination of the need to remove clippings to other areas of the facility or an off-site disposal area.

In areas where clippings cannot be returned (such as greens), they can be blown, dragged, or otherwise moved away, though they should not end up in or near stormwater treatment structures or wetlands. Alternately, clippings can be collected and composted. Composted clippings can be used as soil amendment or fertile topdressing during establishment of new tee, fairway, or rough areas. PGRs can also be used to reduce clipping production.

8.3 Aeration

Cultivation practices – aeration practices and surface cultivation practices – disturb the soil or thatch through the use of various implements to achieve important agronomic goals that include relief of soil compaction, thatch/organic matter reduction, and improved water and air exchange. However, cultivation can require significant time for recovery, thus disrupting play, and should be used judiciously. Cultivation frequency should be based on traffic intensity, level of soil compaction, and the amount of accumulation of excessive thatch and organic matter, which reduces root growth, encourages disease, and creates undesirable playing conditions. Table 9 shows advantages/disadvantages of aeration practices.

Table 9. Turfgrass aeration methods and rankings of agronomic benefits.

Method	Compaction Relief	Thatch control	Water/air movement	Disruption of play
Core aeration	High	Good	High	Medium to high
Deep drilling	Medium	Low	High	High
Solid tining	Low	None	High	Medium-low
High-pressure water injection	None	Low	High	None

8.3.1 Core Aeration

Core aeration is effective at managing soil compaction and aiding in improvement of soil drainage by removing small cores or plugs from the soil profile. Cores are usually 0.25 to 0.75 inches in diameter. Using bigger tines and therefore removing larger cores will disrupt play for longer.

8.3.2 Deep Drilling

Deep-drill aeration creates deep holes in the soil profile through use of drill bits. Soil is brought to the surface and distributed into the canopy. Holes can be backfilled with new root-zone materials if a drill-and-fill machine is used. These machines allow replacement of heavier soils with sand or other materials in an effort to improve water infiltration into the soil profile.

8.3.3 Solid Tining

Solid tining causes less disturbance to the turf surface and can be used to temporarily reduce compaction and soften surface hardness during months when the growth rate of grasses is reduced. However, the benefits of solid-tine aeration are temporary because no soil is removed from the profile, except when using a deep tine aerator with a "kicking action" that results in some soil loosening. "Venting" or "needle-tining" is often used to describe the practice of solid tine aeration using small-diameter tines (0.25 to 0.375 inches). This is an effective tool that can be used to help provide increased gas exchange to root systems and can be particularly useful in alleviating summer stress on putting greens. It can also be performed with minimal impact on putting surface quality when followed by mowing or rolling.

8.3.4 High-pressure Water Injection

High-pressure water injection promotes water penetration and air exchange. Steams of water are injected at high velocities 4 to 8 inches into the soil at 1/8 to ¼ inch diameter. High pressure water injection doesn't disrupt play.

8.4 Surface Cultivation

Surface cultivation manages organic matter accumulation above the soil, reduces the formation of leaf grain, improves infiltration, and improves surface consistency (Table 10). While these methods are generally less disruptive than traditional aeration practices, they usually have a limited to no impact on soil compaction relief.

Table 10. Surface cultivation practices.

Method	Compaction relief	Surface disruption	Water/air movement	Disruption of play
Vertical mowing	Low	Medium – High	Medium	Low - High
Grooming	None	Very low	Very low	None
Spiking/slicing	None	Low	Low	None

8.4.1 Vertical Mowing

Vertical mowing (verticutting) can be incorporated into a cultural management program to achieve a number of goals. The grain of a putting green can be reduced by setting a verticutter to a depth that just nicks the surface of the turf. Deeper penetration of knives will stimulate new growth by cutting through stolons and rhizomes while removing accumulated thatch. Deep vertical mowing (0.5 to 1 inch depth) removes a greater amount of thatch than core aeration and can be considered for aggressive thatch removal as it can remove up to 15% of the thatch at one time. However, it is aggressive and should only be done during less stressful times (e.g. cooler temperatures) and on well-rooted turf. Unlike deep mowing, shallow vertical mowing (0.5 inches or less) does not remove thatch. Instead, it severs stolons to promote new growth while also standing up blades for removal of old growth and minor canopy thinning. Shallow vertical mowing can be practiced regularly during the growing season except in times of drought or excessive heat.

8.4.2 Grooming

Groomers, or miniature vertical mowers attached to the front of reels, are effective at improving management of grain and improving plant density through the cutting of stolons but provide very low or no relief for compaction or thatch.

8.4.3 Spiking/Slicing

Spiking/slicing reduces surface compaction and promotes water infiltration with minimal surface damage. Slicing is faster than core aeration but is less effective. Spiking can break up crusts on the soil surface, and improve water infiltration.

8.5 Topdressing

Topdressing the playing surface with sand is primarily done to improve surface firmness and smoothness, dilute thatch, improve recovery from turf thinning or cultural practices, and, over time, modify the root zone. Topdressing should be of a particle size distribution that is compatible with the existing soil medium to maintain even water distribution in the soil profile. The use of very fine materials can result in layering that impedes uniform water distribution. Topdressing practices can be described as heavy or light for different reasons:

Heavy topdressing, with sand depths up to 0.25 inches, following core aeration and vertical mowing, aids in recovery of turf. Rates can vary based on the various cultural practices that were performed but should not exceed the capacity that the turf canopy can absorb. The use of dry sand helps fill aeration holes completely in one application, as well as speed recovery.

Light and frequent topdressing is important for maintaining a smooth, firm, and uniform playing surface throughout the season, although research has also illustrated that it protects the plant crown from heat and drought stress, equipment traffic, and disease. This supplemental application of sand is also important to do regularly in order to reduce layering in the thatch profile and maintain good water-infiltration rates. Frequency should depend on turfgrass growth potential but can be done as often as weekly. Timing these applications just prior to rain or a deep irrigation cycle can help incorporate the sand into the canopy and minimize any negative impact on mowing equipment the following day.

8.6 Rolling

Rolling of turf is performed at various intervals primarily to help smooth putting surfaces and increase green speed for daily play or tournaments (Figure 18). Periodic rolling of putting surfaces following mowing can increase putting speeds, allowing for improved ball roll without lowering HOC. By increasing green speed, rolling may reduce mowing frequency and thus the stress of mowing. It can also be used to smooth the surface and remove dew in late or early season periods when little shoot growth is occurring.

Figure 18. Rolling of turf is performed at various intervals primarily to help smooth putting surfaces and increase green speed for daily play or tournaments. Photo Credit: Jamie Palokas.

In some instances, “target” rolling of greens can provide an ideal putting surface near the hole where it is most beneficial to the golfer with less effort. While most common in the preparation of golf course greens, rolling should also be considered (and is just recently beginning to be more common) on fairways or tees to reduce the occurrence of some turf diseases. As with all cultural practices, rolling should be done under the appropriate field conditions in order to reduce stress. Adequate soil moisture (but not saturation) reduces the potential for compaction.

8.7 Cultural Best Management Practices

Cultivar Selection Best Management Practices

- Select cultivars that are adapted to the desired use, taking note of disease resistance, spring transition traits, and other traits such as shade and wear tolerance.
- Develop and implement strategies, such as hydro-seeding or hydro-mulching, to effectively control sediment, minimize the loss of topsoil, and protect water quality.

Mowing Best Management Practices

- Tall grass should be mowed frequently, and the height should be gradually decreased until desired HOC is achieved.
- In shaded environments, HOC should be increased by at least 30% to improve the health of turf.
- Consider using a PGR as a regular management tool to improve overall turf health for grasses growing in shaded environments.
- Increase HOC during times of stress (such as drought), as much as use will allow, to increase photosynthetic capacity and rooting depth of plants.
- Mowing frequency should increase during periods of rapid growth and decrease during periods of slow growth.
- Vary mowing patterns.
- On greens, change mowing direction every time.
- Reduce clean-up passes at times of stress.
- Utilize equipment maintenance regimes that allow for best possible quality of cut.
- Use reel mowers whenever possible for maintaining turfgrass that requires HOC below 1.5 inches.
- Keep blades of reel and rotary mowers sharp and properly adjusted.
- Return clippings to canopy whenever possible to recycle nutrients and reduce the need for fertilizer inputs.
- Remove or disperse clippings when the amount is so large that it could smother the underlying grass or on golf greens where clippings might affect ball roll.
- Dispose of collected clippings properly; options include composting or dispersing clippings evenly in natural areas.

Aeration Best Management Practices

- Annual core aeration programs should be designed to remove 15% to 20% of the surface area.
- High-traffic areas may require a minimum of two to four core aerations annually.
- Aeration should take into account when weeds are germinating and should be conducted only when grasses are actively growing and not under stress in order to aid in the quick recovery of surface density.
- Aeration events should be as deep as practical to prevent development of compacted layers in the soil profile as a result of cultivation.
- Solid tine aeration should be avoided on wet native soils because it causes compaction and reduction in water movement.
- Backfill holes with new root-zone materials if a drill-and-fill machine is used.
- High pressure water injection can be applied once every 3-4 weeks throughout the summer.
- Venting should be periodically performed to help provide oxygen to root zones, particularly prior to the onset of summer stress. It can also help dry out excessively wet soils.

Surface Cultivation Best Management Practices

- Aggressive or deep vertical mowing should not be used when the turf is growing slowly.
- Shallow vertical mowing and/or brushing could be utilized during the active growing season on putting greens to prevent excessive thatch accumulation.

Topdressing Best Management Practices

- Topdress the playing surface at a rate that will allow the material to be worked into the canopy without burying the plants.
- During favorable weather conditions, light and frequent applications of topdressing sand on putting greens can smooth out minor surface irregularities, aiding in the prevention of thatch accumulation.
- Use only weed-free topdressing materials with a particle size similar to that of the underlying root zone to dilute thatch.

Rolling Best Management Practices

- Utilize rolling for intensely managed turfgrass to reduce stress, mowing needs, and disease pressure.
- To reduce the potential for compaction, do not roll saturated soils.
- To minimize potential for compaction caused by rolling, use lightweight rollers.
- Consider rolling on fairways or tees as well as on greens to reduce mowing frequency and disease pressure.
- Alternate start/stop points on greens to limit wear, changing directions as with mowing.
- Keep roller off of collars except when exiting/entering the green.

9 INTEGRATED PEST MANAGEMENT

Integrated pest management (IPM) has been described as follows:

> *"IPM is a balanced, tactical approach to pest control. It involves taking action to anticipate pest outbreaks and to prevent potential damage. IPM is a pest management strategy that utilizes a wide range of pest control methods or tactics. The goal of this strategy is to prevent pests from reaching economically or aesthetically damaging levels with the least risk to the environment. Such pest management programs—based on the identification of pests, accurate measurement of pest populations, assessment of damage levels, and knowledge of available pest management strategies or tactics—enable the specialist to make intelligent decisions about control. IPM offers the possibility of improving the effectiveness of pest control programs while reducing some of the negative effects."*

Many people are under the false assumption that IPM represents a non-chemical approach to pest management. In fact, IPM programs use both non-chemical and chemically based methods of pest control. In the long run, this integrated approach is more effective and can be less expensive than traditional pest management approaches that rely only on the use of chemicals. Dealing with pests through an IPM program requires a basic understanding of pest biology and behavior to select effective methods of control. When chemical control is warranted, pesticides should be selected and applied to not only meet regulatory requirements, but also to avoid impacts to non-target species (such as pollinators) and to avoid pesticide runoff or leaching.

9.1 Regulatory Considerations

Federal and state regulations cover practically anyone who manufactures, formulates, markets, stores, handles, or uses pesticides. Pesticides should be used and managed in keeping with regulatory requirements and best practices, as discussed in the "Pesticide Management" and "Maintenance Operations" chapters.

9.2 IPM Overview

IPM is comprised of a range of pest control methods or tactics designed to prevent pests from reaching economically or aesthetically damaging levels with the least risk to the environment. IPM programs have basic components that provide the opportunity to make informed decisions on the control of pests on the golf course. The steps of an effective IPM program are as follows:

1. Identify pests and understand their biology.
2. Monitor the pests to be managed.
3. Develop the pest management goal by setting pest population thresholds.
4. Implement the IPM program.
5. Record and evaluate the results.

IPM also encompasses the prevention of pest problems before they occur by selecting cultivars

for improved pest resistance, using cultural practices to lessen the potential for pest pressure, and improving the effectiveness of pest control programs while reducing some of the negative effects. Chemical controls can be used when needed but should be selected to have minimal effect on beneficial organisms and on the environment and to minimize the development of pesticide resistance. For more information related to selecting appropriate turfgrass cultivars for Delaware and implementing an IPM for turf, see the "Cultural Practices" chapter and the following additional resources:

- Recommended Turfgrass Cultivars for Certified Sod Production and Seed Mixtures in Maryland. 2016. University of Maryland.
- IPM Series: Turf. 2012. University of Maryland Extension.
- Delaware Pesticide Applicator Guide, Delaware Department of Agriculture.

9.2.1 Identifying Pests

A number of key pests can impact turfgrass in Delaware. Being able to identify these key pests and understanding their biology is important to effectively preventing or controlling outbreaks. Once detected, documentation should include mapping on an area map and recording the date of the outbreak. Though pest pressure will often exist when conditions are favorable, the severity is often greatly reduced by using cultural, biological, and genetic management. As a rule, healthy, well-managed turf better withstands pest outbreaks and recovers more rapidly than unhealthy turf. See *Lawn Diseases – Identification and Control* (University of Delaware, 2012) as a reference to turf diseases in Delaware.

9.2.2 Monitoring

Monitoring through scouting or trapping, as well as identifying alternative hosts and overwintering sites for key pests, is a critical element of a successful IPM program. Monitoring will document the presence and development of pests, as well as the conditions that are conducive for pest outbreak throughout the year. It is essential to record the results of monitoring in order to develop historical information, document patterns of pest activity, and track successes and failures.

9.2.3 Pest Thresholds

IPM is commonly used in agricultural crop production, where economic thresholds for key pests have been established. Pest levels exceeding the threshold levels may warrant treatment. Using IPM is more challenging on golf courses than in an agricultural setting, as agricultural thresholds are based on crop yield whereas golf course thresholds are qualitative, involving turfgrass density and playability. Increased education of golfers and maintenance personnel can increase tolerance of minor aesthetic damage without compromising plant health, play, and overall aesthetics. These thresholds can be determined scientifically or based on site-specific experience.

9.3 IPM Implementation

Management practices in each pest category can be utilized to prevent or reduce the amount of pest pressure on turfgrass. Biological controls or chemical controls may be required once pest thresholds are exceeded.

9.3.1 Disease

In the presence of a susceptible host and a conducive environment, plant pathogens can disrupt play by damaging and destroying intensely managed turf. While no measure can completely eliminate the threat of turfgrass disease, turfgrass managers have multiple tactics and tools that can reduce the likelihood of disease. The most common factors that promote turf diseases include close and frequent mowing, poor drainage, excessive thatch, light and frequent irrigation, inadequate or excessive N fertilization, shade, and traffic. For example, summer patch can occur when turf is mowed too closely, given light and frequent irrigations, and fertilized with excessive amounts of N. The use of BMPs for cultural practices promotes healthy, well-managed turfgrass that is less likely to develop disease problems (Figure 19). Disease outbreaks that do occur are less likely to be severe on healthy turf because it has better recuperative potential than stressed, unhealthy turf.

Figure 19. Tree thinning is a cultural practice that can reduce the occurence of disease in turfgrass. Photo Credit: John Jacob.

Common turf diseases in Delaware, symptoms and management options are provided in Table 11. See Diseases of Turfgrass: Identification and Management for specific turf disease information for Delaware. Additional references for turf diseases prevalent in the Mid-Atlantic Region and control methods include:

- Maryland Turfgrass Disease Control Recommendations. 2010. University of Maryland.
- Red Thread and Pink Patch Diseases of Turfgrasses. 2007. University of Maryland.
- Identification and Management of Brown Patch. 2011. University of Maryland.
- Dollar Spot Disease of Turfgrasses. 2003. University of Maryland.
- Summer Patch Disease of Lawn Grasses. 2003. University of Maryland.

Table 11. Common turf diseases, symptoms, and management in Delaware.

Season	Symptoms	Management
Pink Snow Mold		
Very early spring or late winter; can also occur in late fall	Patches of matted leaves that have a pinkish or red-brown color. Patches may be several inches in diameter and center of may be bleached white. Occurs often in areas under snow cover but can also occur during cool periods with high moisture. All turfgrasses are hosts but are not generally killed.	Avoid high nitrogen and remove thatch. Mow late into the fall.
Red Thread		
Primarily in the spring and fall; also during rainy periods in the summer	Irregular blighted patches sometimes with a pink cast. Blades are often water-soaked and covered with the diagnostic pink gelatinous fungal growth. Dead blades in affected areas are straw brown, tan, or slightly pinkish. Dark pink/coral antler like strands of mycelium or lighter colored tufts can be seen extending from the tips of dried infected grass blades. All turfgrasses are hosts especially perennial ryegrass and fine fescues. Affects only the blades does not kill turf.	Maintain adequate nitrogen, remove excess thatch, and reduce stress.
Leaf spot and melting-out		
Leaf spot diseases occur in spring, summer, and fall. Melting-out occurs primarily late spring.	Leaf spots can be brown to purple brown, oval-shaped or elongated, with tan centers. Melting out is more severe and results in dieback of roots and crown and thin turf. Found primarily on Kentucky bluegrass, but all turfgrasses can be infected. Bluegrass can be killed by the root and crown phase (melting-out).	Over-seed bluegrass lawns with a resistant cultivar and avoid high nitrogen.
Necrotic ringspot		
Cool weather in spring and fall.	Rings of dead turf several inches to over a foot in diameter with green turf or weeds in the center. Blades appear yellow to brown; roots and crowns will be decayed. Bluegrass and fine fescues are affected.	Over-seed or replace with tall fescue or ryegrass that are resistant.
Dollar Spot		
Usually late spring through fall.	Leaf spots are hour-glass-shaped, extend across the blade with bleached centers and brown, purple, or black borders. Early in the morning, cottony fungal growth can be seen on infected blades. Bluegrass, ryegrass, and fine fescues are hosts, especially in poorly nourished turfs. Plants are rarely killed, primarily a leaf blight.	Avoid nitrogen deficits, mowing too low, thatch, leaf wetness, and drought stress.
Slime molds		
Usually late spring to fall.	These molds produce a gray or black crusty material on blades of turf. It can be rubbed off easily and appears after a prolonged rainy period. This moldy residue may form on plants in rings or arc patterns. These slime molds are not parasitic and do not harm the plants.	Spore masses can be removed by mowing, raking, or washing with a hose. Control thatch.
Brown patch		
Summer when night temperatures are above 68 degrees F, with high day	Causes a leaf spotting that results in circular brown patches 6 inches to 2 feet and thinned turf. Leaf spots are often irregular and have a thin reddish-brown border. Small patches can coalesce to blight large areas quickly when weather conditions for the disease are ideal. All turfgrass are affected, especially tall fescue and ryegrass.	Avoid high nitrogen in spring, leaf wetness, and excessive thatch.

temperatures and high relative humidity.	Mature turf is rarely killed. One-year-old stands of tall fescue under severe conditions can be killed.	
Summer patch		
Summer, especially during periods of high temperatures and drought.	Diseased areas are first light green then fade rapidly to a straw color (may be confused with wilting). These areas are often circular or sometimes irregular patches often with living grass or weeds in the center. Sometimes smaller patches can merge and blight large areas of turf. Patches can be sunken and leaves at the borders may have a bronzed appearance. Tip dieback of leaves gives the turf a straw-brown color. Bluegrass and fine fescues older than two years are killed by this disease.	Avoid high nitrogen, wet soil, compaction and low mowing.
Slime molds		
Late spring to fall	The spore masses can be removed by mowing, raking, or washing with a hose.	Control thatch.
Pythium blight		
Summer; favors hot, humid periods and poorly drained soils.	Circular small spots are matted, grayish, or water-soaked. Patches will follow surface water flow patterns. Infected blades collapse rapidly, are greasy-looking, and wilt rapidly. Fungal growth can be seen in early morning. Plants will often die in 24 hours. Dead plants are often red-brown to brown in color and matted together. Seeding in the late summer can fail due to Pythium damping-off and blight when overwatered. Bluegrass, fescues, and especially perennial ryegrass are killed by this disease.	Avoid high nitrogen, leaf wetness and thatch. Improve drainage.
Powdery mildew		
Later summer to fall, especially in shady areas.	The leaves of infected pants have a white to gray powdery growth that gives the leaves the appearance of having been dusted with flour or lime. Infected blades may yellow, wither, and die. All turfgrasses can be infected, especially in shady conditions, blights only the leaves.	Avoid high nitrogen, low mowing, increase light levels, or plant shade-tolerant grasses.
Rust		
Fall	Rust-infected turf becomes reddish-brown or yellow. Rust begins as yellow-orange flecks on individual grass blades and develops into orange or brick-red pustules. Spores within the powdery pustule easily rub off when touched. A heavy rusting can cause leaf blades to die and thin stands of susceptible turf. Primarily perennial ryegrass and bluegrass are infected; most turf including zoysia can be infected. Turf can be thinned but rarely is killed.	Avoid low nitrogen and leaf wetness. Plant resistant cultivars.
Fairy rings		
Any time of year.	Rings or arcs of dead grass bordered by inner and outer zones of dark green grass, or rings of very green grass without a dead zone. Rings can be from 1 to 4 feet in diameter or range up to 20 feet. Mushrooms may or not be present in rings. All turfgrass can be affected, especially at dry locations and poorly nourished turf.	Avoid thatch, buried organic debris, and drought stress. Fertilize and rake mushrooms to mask symptoms. Core aeration of stimulated and dead zone, and drenching with an organosilicone wetting agent may alleviate symptoms. Eventually the symptoms will disappear

9.3.2 Weeds

Crabgrass (*Digitaria* spp.), goosegrass (*Eleusine indica*), yellow foxtail (*Setaria glauca*), green kyllinga (*Kyllinga brevifolia)*, yellow nutsedge (*Cyperus esculentus)* and annual bluegrass (*Poa annua*) are among the most common and troublesome turf weeds in Delaware. Weeds such as these compete with desired plants for space, water, light, and nutrients and can harbor insects and diseases. They can be host other pests such as plant pathogens, nematodes, and insects. Weed management is an integrated process in which good cultural practices are employed to encourage desirable turfgrass ground cover and in which herbicides are intelligently selected and judiciously used when needed. For more information on controlling weeds in the Mid-Atlantic Region, including herbicide recommendations, see:

- Weed Control in Turf. University of Delaware Extension.
- Broadleaf Weed Control in Established Lawns. 2005. University of Maryland.
- Herbicides for Crabgrass and Goosegrass Control in Turf. 2008. University of Maryland.
- Guide to Controlling Weeds in Cool Season Turf. 2016. University of Maryland Extension.

9.3.3 Turf Insects/Arthropods

Many arthropods (especially insects and mites) live in turfgrass and the ornamental plant beds on golf courses. Some are beneficial (e.g. pollinators, decomposers, and natural enemies) or are aesthetically attractive (e.g. butterflies), while others may be nuisance pests or may negatively affect plant health. Arthropods can cause various types of damage to turfgrass, depending on where they attack the plant. Annually recurring insect pest groups on Delaware golf courses include species such as armyworms, cutworms, nuisance ants and bees, and annual white grubs.

9.3.4 Annual Bluegrass Weevil

The annual bluegrass weevil (ABW) is a beetle of the weevil family and a pest of short-cut, highly maintained turf in the Northeastern and Mid-Atlantic regions. Damage often is first observed at the edges of greens and fairways with a high proportion of annual bluegrass (*Poa annua*). Most damage is caused by larvae, which may go unnoticed for many weeks. Significant damage from first-generation ABW generally becomes obvious in late May or early June and often is mistaken for other problems. Damage from second-generation ABW occurs in late July until early August. Evidence of ABW damage includes damaged stems, which can easily be pulled away from the crowns, and hollowed stems with sawdust-like frass (excrement), which is a key diagnostic feature. Older larvae may be detected by cutting into the turf and examining the area between turf and thatch.

An appropriate early-season damage threshold is 30 to 80 larvae per square foot. That threshold decreases as turf gets more stressed. Monitoring methods include soap flushing the turf with a solution of dishwashing detergent (0.5 ounces detergent per gallon water) to force adults to the surface. Other monitoring techniques include black light traps, pitfall traps, vacuuming adults, growing degrees days, weevil trak, and phenological indicators.

In addition to chemical control, cultural management options should be considered, primarily converting from a susceptible turf species to one that has increased tolerance to ABW. Perennial ryegrass is resistant to ABW. Because ABW overwinters in pine litter and leaves, removing this material may help to reduce populations. Proper nutrition and irrigation often help mask symptoms of ABW damage.

For more information on ABW biology and control in the Mid-Atlantic, see Biology and Management of the Annual Bluegrass Weevil. 2005. University of Maryland.

9.3.5 Nematodes

Plant-parasitic nematodes adversely affect turfgrass health by debilitating the root system of susceptible turfgrass and decreasing water and nutrient uptake efficiency. Additionally, weakened turf favors pest infestation, especially troublesome weeds that necessitate herbicide applications. Over time, turf in the affected areas thins out and, with severe infestations, may die. The roots of turfgrass under nematode attack may be very short, with few, if any, root hairs, or they may appear dark and rotten. Turfgrass usually begins showing signs of nematode injury during additional stresses, including drought, high temperatures, low temperatures, and wear. Cultural practices and nematicides can help control nematodes.

9.3.6 Biological Controls

The biological component of IPM involves the release and/or conservation of natural predators, such as parasites and pathogens, and other beneficial organisms. Biofungicides, or formulations of living organisms used to control the activity of plant pathogenic fungi and bacteria, are commercially available. Natural enemies (including ladybird beetles, green lacewings, and mantids) may be purchased and released near pest infestations. Areas on the golf course can also be modified to better support natural predators and beneficial organism populations.

9.3.7 Conventional Pesticides

A pest-control strategy using pesticides should be used when the pest is causing or is expected to cause more damage than what can be reasonably and economically tolerated. Pesticides should be evaluated on effectiveness against the pest, mode of action, life stage of the pest, potential human health hazards, non-target effects, potential off-site movement, and cost. A control strategy should be implemented that reduces the pest numbers to an acceptable level while minimizing harm to non-targeted organisms or the environment. In addition, the use of pesticides should be consistent with guidelines to reduce resistance in pest species. Lastly, pesticides must always be used as directed on the product label, as required by state and federal law.

9.4 Record Keeping and Evaluation

It is essential to record the results of scouting in order to develop historical information, document patterns of pest activity, and track successes and failures. Records of pesticide use are required by DDA regulations, but for IPM purposes should include additional information, such as monitoring records, weather records, cultural management logs, and pest response.

9.5 IPM Best Management Practices

Basic IPM Best Management Practices

- Develop a written IPM plan for your golf course. (Available resources for writing an IPM plan include the GCSAA and Greengolfusa.com.)
- Select turfgrass cultivars recommended for use in Delaware and best suited for the intended use and the environmental conditions of the specific site.
- Correct soil physical and chemical properties that may impact turfgrass health and its ability to resist pests.
- Evaluate the potential impact of the timing of cultural practices and fertilizer applications on the incidence of pest problems.
- Divert traffic away from areas that are stressed by insects, nematodes, diseases, or weeds.
- When chemical control is necessary, follow Delaware recommendations to select the most effective pesticide with the lowest toxicity and least potential for off-target movement for a given weed, pathogen, or insect.
- Document all IPM-related activities, including pesticide usage.

Pest Identification Best Management Practices

- Identify key pests on key plants.
- Determine the pest's life cycle and know which life stage to target (e.g. for insect pests, whether it is an egg, larva/nymph, pupa, or adult).
- For diseases, correctly identify the disease pathogen. This often involves sending samples to diagnostic clinics.
- Identify weeds accurately.
- Consider targeted pest control measures rather than blanket applications of pesticides.

Monitoring Best Management Practices

- Monitor prevailing environmental conditions for their potential impact on pest problems.
- Train personnel how to regularly monitor pests by scouting or trapping.
- Identify alternative hosts and overwintering sites for key pests.
- Correctly identify the specific disease, weed, and/or insect problem to ensure appropriate control measures.
- Assess pest damage when it occurs, noting particular problem areas, such as the edges of fairways, shady areas, or poorly drained areas.
- Document when the damage occurred. Note the time of day, date, and flowering stages of nearby plants.
- Map pest outbreak locations to identify patterns and susceptible areas for future target applications.

Pest Threshold Best Management Practices

- Establish threshold levels for key pests and document in the written IPM plan.

Weed Control Best Management Practices

- To prevent weed encroachment, adopt or maintain cultural practices that protect turfgrass from environmental stresses such as shade, drought, and extreme temperatures.
- To reduce weed infestation, address improper turf management practices, such as the misuse of fertilizers and chemicals, improper mowing height or mowing frequency, improper soil aeration, and physical damage and compaction from excessive traffic.
- Fertilize adequately to sustain desirable color, growth density, and vigor and to better resist diseases, weeds, and insects.
- Weed-free materials should be used for topdressing.
- Address damage from turfgrass pests such as diseases, insects, nematodes, and animals to prevent density/canopy loss to weeds.

Disease Control Best Management Practices

- Ensure that proper cultural practices and traffic control that reduce turfgrass stress are used.
- Correct conditions that produce stressful environments for the turf (e.g. improve airflow and drainage and reduce or eliminate shade.)
- Fungicide use should be integrated into an overall management strategy for a golf course.
- Apply a preventative pesticide to susceptible turfgrass when unacceptable levels of disease are likely to occur.

Insects/Arthropods Control Best Management Practices

- Release insect-parasitic nematodes to naturally suppress insect pests such as white grubs.
- For insecticide application aimed at soil insects, irrigate turfgrass before and/or after an application, in accordance with the label.

Annual Bluegrass Weevil Best Management Practices

- Reduce the amount of annual bluegrass in infested areas.
- Remove overwintering habitat (i.e. pine litter and leaves).
- Monitor in the spring as adults migrate from overwintering and time insecticide applications for adults at peak migration time.
- Replace turf with species less susceptible species annual bluegrass weevil.

Nematode Control Best Management Practices

- When nematode activity is suspected, an assay of soil and turfgrass roots is recommended to determine the extent of the problem.
- Increase mowing height to reduce plant stress.
- Irrigate deeply but infrequently.
- Use proper amounts of N, P, and K fertilizers at the appropriate times of year.
- Reduce or eliminate other biotic and abiotic stresses when nematodes are compromising the root system and plant health.

Biological Controls Best Management Practices

- Identify areas on the golf course that can be modified to attract natural predators, provide habitat for them, and protect them from pesticide applications.
- Install flowering plants that can provide parasitoids with nectar, or sucking insects (aphids, mealybugs, and soft scales) with a food source.
- Avoid applying pesticides to roughs, driving ranges, or other low-use areas to provide a refuge for beneficial organisms.

Conventional Pesticides Best Management Practices

- Train employees in proper pest identification and pesticide selection techniques.
- Follow a selection process to select the best site- and pest-specific product with the lowest potential to have off target effects.
- Purchase, mix, and apply only the quantity of pesticide needed in order to avoid disposal problems, protect non-target organisms, and reduce costs.
- Follow the label and read the entire pesticide label before handling or applying pesticide.
- Spot-treat pests whenever appropriate.
- Make note of any environmental hazards and groundwater advisories included on the label.
- Rotate pesticide chemistries (modes-of-action) to reduce the likelihood of resistance.
- Follow guidelines and advice provided by the Fungicide Resistance Action Committee (FRAC), Herbicide Resistance Action Committee (HRAC), and Insecticide Resistance Action Committee (IRAC).

Record Keeping and Evaluation Best Management Practices

- Determine whether the corrective actions effectively reduced or prevented pest populations, were economical, and minimized risks. Record and use this information to assist in making similar decisions in the future.
- Observe and document turf conditions regularly (daily, weekly, or monthly, depending on the pest), noting which pests are present, so that informed decisions can be made regarding the damage they are causing and what control strategies are necessary.

10 PESTICIDE MANAGEMENT

Pesticide use should be part of an overall IPM strategy that includes biological controls, cultural methods, pest monitoring, and other applicable practices, as discussed in the "Integrated Pest Management" chapter of this document. When a pesticide application is deemed necessary, product selection should be based on effectiveness, toxicity to humans and non-target species, cost, site characteristics, and persistence and other factors that may impact the environment.

Storage and handling of pesticides in their concentrated form poses the highest potential risk to groundwater or surface water. For this reason, it is essential that, in addition to compliance with state and federal laws, careful consideration be given to site selection, design, construction and operation of facilities and areas used for storing and handling pesticides be properly, designed, constructed, and operated in accordance with federal and Delaware regulations.

10.1 Regulatory Considerations

Pesticides contain active ingredients, which target the pest, and inert ingredients, such as solvents, surfactants, and carriers. Both active and inert ingredients are regulated by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as well as by state and local laws, due to environmental and health concerns. The DDA Pesticide Regulation Section is designated as the lead agency for enforcement of the Delaware Pesticide Law. As such, DDA is responsible for:

- Regulating the use, sale, storage, and disposal of pesticides.
- Certifying pesticide applicators.
- Ensuring that pesticides are applied by competent individuals.
- Establishing guidelines for the application of pesticides.

In addition to federal registration as required under FIFRA, all pesticide products distributed, sold, or transported in Delaware must be registered with the Pesticides Section of the DDA. The Delaware Pesticide Registration and Labeling Law requires a distributor of a pesticide product to register every pesticide product each year with the DDA before that product can be sold or distributed in the state. The DDA maintains a database of pesticides registered in the state which can be searched on line.

In Delaware, pesticide storage areas must meet federal minimum requirements set by United States Environmental Protection Agency:

- The storage area must be secured or locked to prevent unauthorized access.
- Pesticides must be stored in a separate building or, at a minimum, must be separated by a physical barrier from living and working areas and from food, feed, fertilizer, seed, and safety equipment.
- A warning sign approved by DDA must be placed on the exterior of the storage area.
- Pesticides must be stored in a dry, ventilated area.
- The pesticide storage area must be kept clean.

- A supply of absorbent material sufficient enough to absorb a spill equivalent to the capacity of the largest container in storage must be kept in the storage area.
- The storage area must contain only pesticide containers that are properly labeled and are free of leaks.
- The storage area must have an appropriate fire extinguisher available.
- Pesticides must be stored in an area located at least 50 feet from any water well or stored in secondary containment approved by DDA.

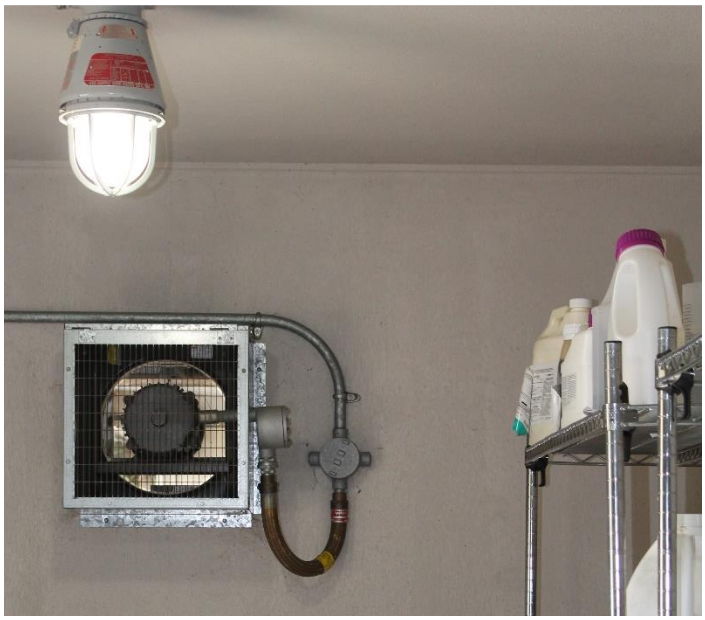


Figure 20. Pesticide storage areas must be adequately ventilated. Photo Credit: Erik Ervin.

Figure 21. The use of metal shelving in pesticide storage areas is a BMP. Photo Credit: Erik Ervin.

The use of aquatic pesticides is subject to a recent court decision, which mandated that USEPA and all state environmental agencies permit pesticide applications in/near water. In Delaware, this requirement is regulated under the National Pollutant Discharge Elimination System (NPDES) program administered through DNREC. As a result, DNREC's Secretary signed a Secretary's Order to adopt emergency regulations, Regulations Governing the Discharges from the Application of Pesticides to Waters of the State. For more information, see the FAQ published by DNREC and the Aquatic Pesticides Section of DNREC.

10.2 Human Health Risks

Pesticide chemical classifications that vary greatly in their toxicity to human health, non-target organisms, and the environment. This is true with pesticides that are considered conventional and organic. The human health risk associated with any pesticide use is related to both pesticide toxicity and level of exposure. Immediate attention, and specific care and treatment depends on the type of pesticide and the route of exposure. The pesticide label provides information on personal protective equipment (PPE) required to minimize exposure, and first aid information specific to the product. Therefore, applicators should always read and follow the label before using a pesticide in addition to following standard safe practices.

Safety Data Sheets (SDS) (formerly Material Safety Data Sheets [MSDS]) also provide important information on hazardous chemicals. Using SDS in conjunction with the product label will provide not only a good description of the potential risks, but also appropriate and required exposure minimization measures that will help reduce any such risks.

For more information, see the following publications:

- Pesticide Information Leaflet No. 11: Practices for Safe Use. 2013. University of Maryland Extension.
- Pesticide Information Leaflet No. 28: How to Read a Pesticide Label. 2013. University of Maryland Extension.
- Pesticide Information Leaflet No. 29: How to Read a Material Safety Data Sheet (MSDS). 2013. University of Maryland Extension.
- Pesticide Information Leaflet No. 46: First Aid for Pesticide Emergencies. 2013. University of Maryland Extension.

10.3 Personal Protective Equipment

Exposure to pesticides can be mitigated by practicing good work habits and using pesticide mix/load equipment (e.g., closed loading) that reduce potential exposure. PPE, such as specific types of clothing, goggles, respirators, etc., protects workers from one or more of the following routes of exposure: skin, eyes, oral ingestion, or respiratory tract (Figure 22). Pesticide labels list legal requirements for specific required. However, as a habit, minimum PPE should be gloves, long sleeve shirt and pants (or similar coverall), socks, and shoes. SDS also provide information on appropriate PPE to wear while handling the product as formulated. To avoid contamination,

PPE should not be stored in a pesticide storage area. For more information, see the Personal Protective Equipment information on the Pesticide Environmental Stewardship website.

Figure 22. PPE protects against exposure to pesticides during mixing/loading. Photo Credit: Erik Ervin.

10.4 Environmental Fate and Transport

Potential environmental impact of a pesticide can often be determined by the environmental hazards statement found on product label. The environmental hazards statement (referred to as "Environmental Hazards" on the label and found under the general heading "Precautionary Statements") provides the precautionary language advising the user of product specific concerns. Potential environmental impacts include contamination of surface water or groundwater and toxicity to non-target organisms, especially aquatic species.

The key to preventing pesticide impacts on the environment is an understanding of the physical and chemical characteristics that determine a pesticide's interaction with the environment: solubility, adsorption, persistence, and volatilization. These characteristics influence the potential for pesticide runoff, leaching, or drift. Once applied, pesticides can move off-site in several ways: in water, in air, attached to soil particles, and on or in objects, plants, or animals.

To prevent the off-site movement of pesticides, site-specific characteristics and prevailing conditions should be evaluated, and taken into consideration to ensure selection of the appropriate pesticide. Site-specific characteristics, such as soil type, leaching potential of the chemical, depth to the water table, geology, and proximity to surface water should all be considered before selecting and applying pesticides. For example, highly permeable materials such as gravel deposits or the sandy soils characteristic of much of Delaware allow water and dissolved compounds to freely percolate down to groundwater.

In addition to site characteristics, prevailing weather conditions, such as chance of precipitation, prevailing wind, temperature humidity, etc., should be evaluated with respect to the timing of pesticide applications. For example, if rainfall is high and soils are permeable, water that carries dissolved pesticides may take only a few days to percolate downward to the groundwater.

10.4.1 Leaching and Runoff

Most pesticide movement in water is either by surface movement off the treated site (runoff) or by downward movement through the soil (leaching). Runoff and leaching may occur when:

- Too much pesticide is applied or spilled onto a surface.
- Too much rainwater or irrigation water moves pesticide through the soil off-site or into groundwater.
- Highly water-soluble or persistent pesticides are used.
- Soil structure

The mobility of a substance in soil is referred to as a Soil Adsorption Coefficient (Kd/Koc). Weakly sorbed pesticides (compounds with small Koc values) are more likely to leach through the soil and reach groundwater. Just the opposite is the case with strongly sorbed pesticides (compounds with large Koc values) which are more likely to remain near the soil surface, reducing the likelihood of leaching but increasing the chances of being carried to surface water via runoff or soil erosion.

10.4.2 Drift

Pesticide movement away from the application site by wind or air currents is called drift. Pesticides may be carried off-site in the air as spray droplets, vapors, or solid particles, even on blowing soil particles.

Air drift: Air drift is a function of droplet size. Small, fine drops with diameters of 100 microns or less tend to drift away from targeted areas.

Vapor drift: Volatile pesticides can change readily from a solid or liquid form into a gas under the right conditions (i.e., high temperatures) and cause vapor drift.

Particle drift: Particle drift is the movement of solid particles from the target area by air during or just after an application. These solid particles may include pesticides formulated as dust or soil particles to which pesticides are attached.

Application techniques, the type of equipment used, and nozzle size, greatly influence the amount of drift that may occur. Nozzle selection and coverage, in particular, is important in the control of drift. The type of nozzle, nozzle orifice size, sprayer pressure, and the height or distance of the nozzles from the target affect the potential for off-site movement of pesticides. A nozzle that primarily produces coarse droplets is usually selected to minimize off-target drift. The pesticide label should be reviewed for specific information on drift reduction techniques or requirements.

Environmental fate- and transport-related topics are covered in greater detail in the following publications:

- Chapter 7 “Pesticides in the Environment” of the Maryland Pesticide Applicator Core Manual.
- Pesticide Information Leaflet No. 8: Factors Affecting Groundwater Contamination. 2012. University of Maryland Extension.
- Pesticide Information Leaflet No. 9: Protecting Groundwater from Pesticides. 2012. University of Maryland Extension.

10.5 Application Equipment and Calibration

Application equipment must ensure that the pesticide reaches the intended target at the proper rate. Information on the label specifies the legal application rate and sometimes suggests the appropriate equipment for use with the product. While different kinds of application equipment are available, nearly 90% of all pesticides are formulated for spraying. The size of the equipment (tank size, boom width, etc.) should be matched to the scale of the facility and areas of application.

To apply pesticides at the proper rate, properly calibrated application equipment is essential. These practices help mitigate environmental and human health concerns, reduce the chances of over- or under-applying pesticides and optimize pesticide efficacy. Equipment should also be checked frequently for leaks and malfunctions and repaired promptly.

For more information on pesticide application equipment and calibration, see Chapter 11 "Pesticide Application Procedures" in the Maryland Pesticide Applicator Core Manual.

10.6 Pesticide Record Keeping

Maintaining accurate records of pesticide-related activities (for example, purchasing, storage, inventory, applications, etc.) is essential to an effective pest management program. Delaware pesticide regulations require records of Restricted Use Pesticides applications must be kept and retained for two years. The following information must be documented:

- name of applicator and certification #
- date and time of application
- location of application
- area treated and number of acres
- pest and type of plant
- product name, active ingredient, and EPA registration number of pesticides used
- rate of concentration of pesticide used
- total amount of pesticide used
- restricted entry interval, re-entry date/time
- posting requirements and information
- temperature

- wind direction/speed
- relative humidity

DDA provides a pesticide application recommended form that provides compliance guidance for the keeping of pesticide application records in accordance with state and federal regulations.

10.7 Pesticide Transportation, Storage, and Handling

Storage and handling of pesticides in their concentrated form poses the highest potential risk to groundwater or surface waters. For this reason, it is essential that facilities for storing and handling these products be properly sited, designed, constructed, and operated. In addition, storing large quantities of pesticides for long periods of time should be avoided. Adopting a "first in-first out" management system for pesticide purchase and storage helps to avoid a buildup of large quantities of chemicals.

At a minimum, Delaware regulations require that pesticide storage areas must meet requirements as described previously under Regulatory Considerations section of this chapter. For more information on pesticide storage recommendations, see the following:

- Pesticide Storage Facilities. 2004. Rutgers University.
- Store Pesticides Safely. 2016. Clemson University.
- Pesticide Storage, Pesticide Environmental Stewardship website.
- Pesticide Information Leaflet No. 39: Pesticide Storage and Security. 2012. University of Maryland.

10.8 Mixing/Washing Station

Proper cleaning of equipment helps prevent residues from reaching surface waters, groundwater, drainage pipes, or storm sewers. The residues from washing equipment include grass clippings, soil, soaps, oil, fertilizers, and pesticides. Therefore, equipment washing should be conducted under controlled conditions in an appropriate contained area with minimal risk to the environment and to prevent adverse washwater and stormwater runoff impacts. Equipment washing guidelines and restrictions should be established that reduce the potential for pollutants to reach stormwater runoff, surface water or groundwater.

Figure 23. Mixing/washing station at Deerfield. Photo Credit: Erik Ervin.

For equipment with pesticide residues, BMPs should be followed to ensure that washwater does not become pollution source. Captured washwater can be used as a dilute pesticide per label, or it may be pumped into a rinsate storage tank for use in the next application and used as a dilute pesticide per the label.

For more information on pesticide equipment cleaning, see the following publications:

- Cleaning Your Sprayer. 2012. Cornell University.
- Maintenance, Cleaning and Storage of Ground Sprayers. 2017. Montana State University.
- Sprayer Clean-Out Guidelines. 2012. University of Delaware Cooperative Extension.
- Cleaning Pesticide Application Equipment. 2018. University of Nebraska Extension.

10.9 Disposal

There is usually no safe and legal way to dispose of leftover pesticide from professional applications and therefore all of the chemical must be used according to directions on the label. This includes wash water from pesticide equipment washing, which must be used in accordance with the label instructions.

Often pesticide storage facilities accumulate unusable or unwanted pesticide products. They can accumulate for a variety of reasons, e.g. mistakes made in calculating the amount of product needed or the launch of new product chemistries that may be more effective at controlling target pests. Disposing of these stockpiles properly may be challenging. Simply keeping them in storage eventually becomes problematic when packaging inevitably deteriorates or corrodes and creates a hazard. The DDA's Environmental Sweep Program offers environmentally responsible

disposal of unwanted, outdated or cancelled pesticides to qualifying individuals and businesses, including golf courses. This program offers free removal of up to 500 pounds or 50 gallons of pesticides, picked up by a waste disposal contractor.

10.10 Pesticide Container Management

Handling of empty pesticide containers must be done in accordance with label directions as well as with all federal, state, and local laws and regulations. Under the federal Resource Conservation and Recovery Act, a pesticide container is not empty until it has been properly rinsed. However, pesticide containers that have been properly rinsed can be handled and disposed of as non-hazardous solid waste. Federal law (FIFRA) and state law requires pesticide applicators to rinse all empty pesticide containers before taking other container disposal steps. For more information on proper pesticide container disposal procedures, see Pesticide Information Leaflet No. 13: Disposal of Pesticide Containers. 2012. University of Maryland.

After following proper procedures (such as pressure rinsing, triple rinsing, puncturing, etc.), pesticide containers be either recycled through an approved program or disposed of by depositing them in a licensed sanitary landfill. DDA's Pesticide Section, in cooperation with the Ag Container Recycling Council (ACRC), provides an empty pesticide container recycling program in the State of Delaware. For more information, see the DDA's Pesticide Calendar of Events web page.

10.11 Pesticide Management Best Management Practices

Human Health Risks Best Management Practices

- Select the least toxic pesticide with the lowest exposure potential.
- Read the pesticide label before mixing or applying a pesticide.
- Use appropriate PPE as per the pesticide label.
- Follow standard safe practices for the use of pesticides.
- In case of exposure, refer to the pesticide label and SDS for more information.

PPE Best Management Practices

- Provide adequate PPE for all employees who work with pesticides (including equipment technicians who service pesticide application equipment).
- Ensure that PPE is sized appropriately for each person using it.
- Make certain that PPE meets the minimum requirements listed on the pesticide label.
- Ensure that PPE meets rigorous testing standards and is not just the least expensive.
- Store PPE where it is easily accessible, but not in the pesticide storage area.
- Forbid employees who apply pesticides from wearing facility uniforms home.
- Wear gloves with sleeves out over the top of the glove to avoid the potential for pesticides to get inside the glove and expose skin. For overhead applications, gloves

should be worn over the top of the sleeves and cuffed to catch any potential pesticide residue

- Meet requirements for the Occupational Safety and Health Administration (OSHA) 1910.134 Respiratory Protection Program. The major purpose of this federal law requires medical evaluation and fit testing of workers who are applying pesticides with a label requirement requiring tight-fitting respirators. Employers are required to provide these services for workers.

Environmental Fate and Transport Best Management Practices

- Use drift retardants when needed which will reduce spray drift by hindering formation of small, drift-prone droplets.
- Consider pesticide sorption principles in selecting pesticides.
- Understand site characteristics that are prone to leaching losses (e.g., sand-based putting greens, coarse-textured soils, and shallow water tables) and select pesticides for these areas that have a low leaching potential.
- Understand site characteristics that are prone to runoff losses (such as steep slopes) and select pesticides for these areas with a reduced runoff potential.
- Select pesticides with reduced impact on pollinators.
- Select pesticides that, when applied according to the label, have no known effect on listed species or species of concern present on the facility.
- Time product applications for favorable prevailing conditions.
- Do not make applications during windy conditions or during temperature inversions.
- Avoid using volatile pesticides. If used, follow precautionary statements on the label and do not apply during high temperatures.
- Apply pesticides at the appropriate rate and prevent unintended releases.
- Exercise caution when using spray adjuvants that may facilitate off-target movement.
- Schedule the timing and amount of irrigation needed to water in products (unless otherwise indicated on label) without over-irrigating.
- Select spray nozzle sizes and types that produce droplets that are less likely to drift off target.

Application Equipment Best Management Practices

- Use an appropriately sized application equipment for the size of area being treated.
- Ensure the spray technician is experienced, properly trained, and preferably certified as a pesticide applicator.
- Minimize off-target movement by using properly configured application equipment with nozzles selected to ensure coverage while minimizing drift.
- Properly calibrate all application equipment at the beginning of each season (at a minimum) or after equipment modifications.
- Check equipment daily when in use.
- Use recommended spray volumes for the targeted pest to maximize efficacy.
- Calibration of walk-behind applicators or backpack sprayers should be conducted for each person making the application to take into consideration their walking speed, etc.

Pesticide Record Keeping Best Management Practices

- Keep and maintain records of pesticides used in order to meet legal (federal, state, and local) reporting requirements.
- Records should be completed as soon as possible after the application is completed.
- Use records to monitor pest control efforts and to plan future management actions.
- Use electronic or hard-copy forms and software tools to properly track pesticide inventory and use.
- Develop and implement a pesticide drift management plan.
- Keep a backup set of records in a safe but separate storage area.

Pesticide Transport, Storage, and Handling Best Management Practices

- Maintain an up-to-date inventory of all pesticides purchased, including date of purchase and current quantity in inventory, and the SDS for each chemical.
- Avoid purchasing large quantities of pesticides that require storage for greater than six months.
- Adopt the "first in–first out" principle, using the oldest products first to ensure that the product shelf life does not expire.
- Store, mix, and load pesticides away from sites that directly link to surface water or groundwater.
- Store pesticides in a lockable concrete or metal building that is separate from other buildings.
- Clearly identify the building as a pesticide storage area.
- Locate pesticide storage facilities away from other structures to allow fire department access.
- Storage facility floors should be impervious and sealed with a chemical-resistant paint.
- Floors should have a continuous sill to retain spilled materials and no drains, although a sump may be included.
- Sloped ramps should be provided at the entrance to allow the use of wheeled handcarts for moving material in and out of the storage area safely.
- Shelving should be made of sturdy plastic or reinforced metal.
- Metal shelving should be kept painted to avoid corrosion. Wood shelving should never be used, because it may absorb spilled pesticides.
- Always store dry materials above liquid products.
- Store herbicides separate from other pesticide products to avoid confusion of products and misapplication.
- When possible, provide secondary containment options.
- Automatic exhaust fans and an emergency wash area should be provided. Light and fan switches should be located outside the building, so that both can be turned on before staff enter the building and turned off after they leave the building.
- Avoid temperature extremes inside the pesticide storage facility.
- PPE should be easily accessible and stored outside the pesticide storage area.
- Do not transport pesticides in the passenger section of a vehicle.
- Never leave pesticides unattended during transport.

- Place a spill containment kit in the storage area, in the mix/load area, transportation vehicle, and on the spray rig.

Mixing/Washing Station Best Management Practices

- Loading pesticides and mixing them with water or oil diluents should be done over an impermeable surface (such as lined or sealed concrete), so that spills can be collected and managed.
- Mixing station surface should provide for easy cleaning and recovery of spilled materials.
- Pump the sump dry and clean it at the end of each day. Liquids and sediments should also be removed from the sump and the pad whenever pesticide materials are changed to an incompatible product (i.e., one that cannot be legally applied to the same site).
- Apply liquids and sediments as you would a pesticide, strictly following label instructions.
- Absorbents such as non-clay based cat litter or sand may be used to clean up small spills and then applied as a topdressing in accordance with the label rates or disposed of as a waste.
- Sweep up solid materials and use as per label.

Disposal Best Management Practices

- Collect wash water (from both inside and outside the application equipment) and use it as a pesticide in accordance with the label instructions.
- The rinsate may be applied as a pesticide (preferred) according to the product label directions or stored for use for the next compatible application.

Pesticide Container Management Best Management Practices

- Triple rinse or pressure rinse pesticide containers immediately in order to remove the most residue.
- Rinse containers during the mixing and loading process and add rinsate water to the finished spray mix.
- Puncture empty and rinsed pesticide containers and dispose of according to the label.
- Recycle pesticide containers when possible. The DDA Pesticide Section, in cooperation with the Ag Container Recycling Council (ACRC), provides an empty pesticide container recycling program in the State of Delaware. For more information, see https://agriculture.delaware.gov/pesticide-management/calendar/ and https://agriculture.delaware.gov/pesticide-management/environmental-sweep-program/.

11 POLLINATOR PROTECTION

Most flowering plants need pollination to reproduce and grow fruit. While some plants are pollinated by wind, many require assistance from insects and other animals. Farmers throughout Delaware depend on both honey bees and native bees to pollinate their crops each year. It takes nearly 300 million honey bees to successfully pollinate these crops, which contributes more than $38.7 million to the state's economy annually. As of 2018, 289 beekeepers with 5,934 colonies in-state are registered with the Delaware Department of Agriculture.

Both wild and managed bees are facing threats that can alter their health, abundance, and distribution. These threats include parasites, diseases, and other pathogens, lack of genetic diversity, poor nutrition due to monoculture agriculture, stress in adult bees caused by transportation and overcrowding, and exposure to pesticides. Research indicates that some pesticides can be harmful for pollinators and can have negative effects at the sub-individual level (such as gene expression or physiology), individual level (such as mortality, foraging, or learning), or even the colony level (such as colony growth, overwintering, or honey production).

Because of the potential for non-target effects of products used in golf course management, pesticide applicators need to be mindful of the impact that pesticides have on pollinator species and their habitat. In addition to adhering to best management practices related to pesticide application, golf course managers can protect and enhance habitat on the course in a number of ways to help both wild pollinators and managed bees. For more information, see the Delaware Pollinator Protection Plan.

Figure 24. Examples of Delaware pollinators. Photo Credit: Deborah Delaney.

11.1 Regulatory Considerations

Pollinator protection language is a requirement for pesticide labels. Following the label is mandatory. Pesticide applicators must be aware of honey bee toxicity groups and be able to understand precautionary statements (Figure 25). In addition, they should be aware of the behavior of honey bees, wild bees, and other pollinators that may visit golf courses, and they should avoid applying pesticides when and where these insects may be present. They should also understand the effects of pesticides on bees and other pollinators, as well as the routes of exposure. The USGA publication *Making Room for Native Pollinators* provides the basics of pollinator biology useful for pesticide applicators. The Pollinator Partnership has published visual depictions of honey bee, solitary bee, colony, and general pollinator life cycles that are useful as well.

Recordkeeping may be required by law in order to use some products. IPM principles include keeping records of both pests and pest control activity so that records may be referred to for information on past infestations and effectiveness of controls to better inform future management actions.

Some golf courses maintain hives of domestic bees. In Delaware, managed hives must be registered with the State Apiarist in writing within 10 days of the time the bees are acquired and annually after that on or before January 30th of each year.

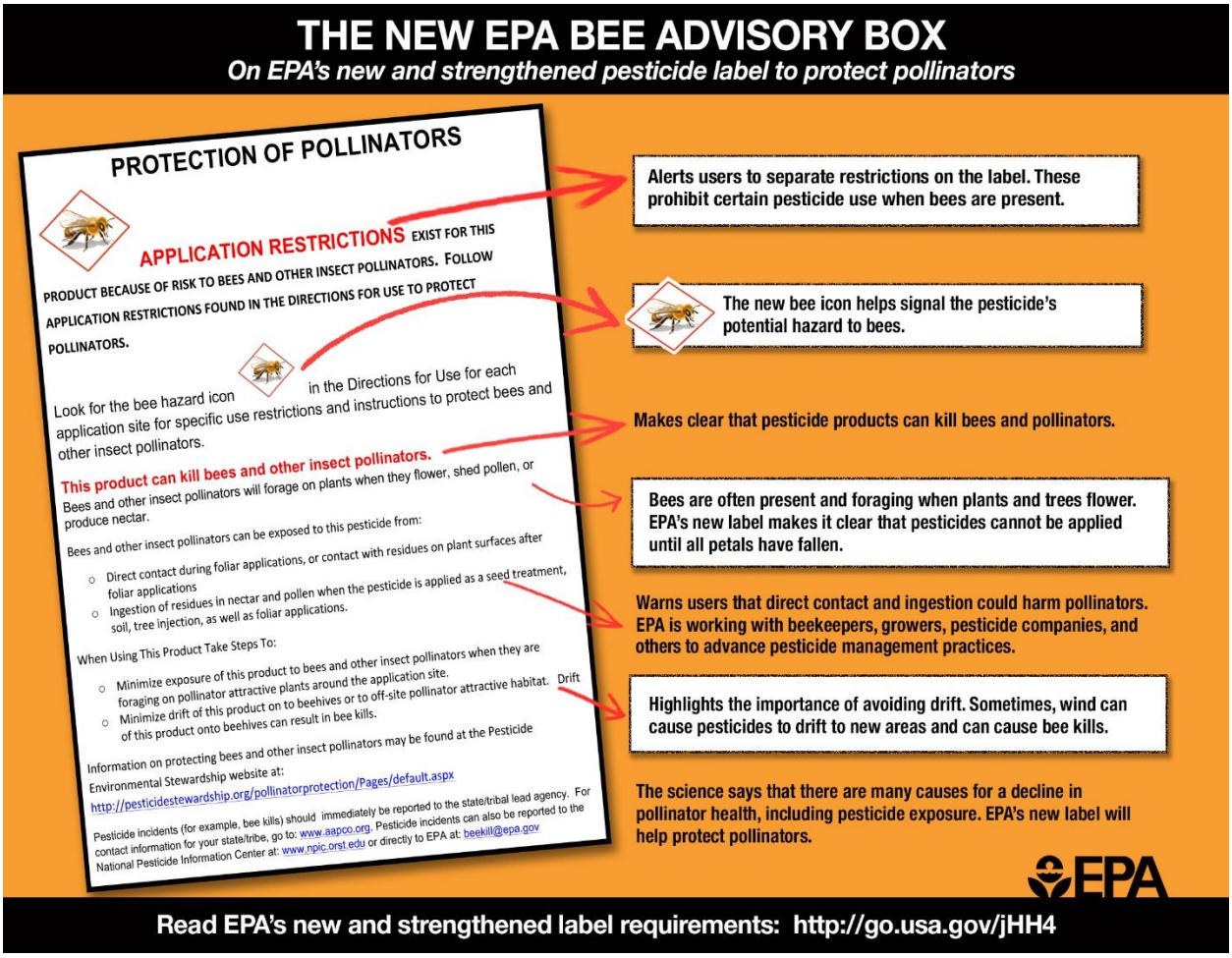


Figure 25. Following the pesticide label is a regulatory requirement. The Bee Advisory Box was added to pesticide labels in 2013.

11.2 Pest Management Practices that Reduce Impacts on Pollinators

Protecting pollinators on the golf course does not preclude the use of pesticides, but instead minimizes the potential impact from these chemicals. Pesticide applicators must use appropriate tools to help manage pests while safeguarding pollinators, the environment, and humans. Using IPM best management practices is an important key to protecting pollinators because they reduce pesticide usage and minimize the potential of exposure. Superintendents can utilize IPM best management practices for turf that protect pollinators by following these simple steps:

- Identifying what is truly a pest. (For example, solitary ground-nesting bees and wasps might be alarming, but most are harmless.)
- Setting higher weed thresholds in low-use areas.
- Monitoring bee activity to avoid applying pesticides during peak activity times (i.e. applying pesticides in the early morning or evening).

When the use of pesticides is necessary, being mindful of pollinators includes selecting

chemicals with low toxicity to bees, short residual toxicity, or properties repellent to bees; using caution when applying near flowering plants, including flowering weeds (mow first whenever possible); and avoiding drift. In addition, applicators are also encouraged to utilize FieldWatch to locate any nearby apiaries before applying pesticides on the course.

11.3 Preserving and Enhancing Habitat on the Course

Habitat for pollinators includes foraging habitat, nesting sites, and water sources. Pollinator-friendly habitat contains a diversity of blooming plants of different colors and heights, with blossoms throughout the entire growing season. Native plants are best for providing the most nutritious food source for native pollinators. DDA maintains a list of sources for native plants in the state. Even plants considered weeds provide important habitat. For example, red clover offers an important nectar and pollen source.

Increasing habitat to meet pollinator needs can be accomplished simply by adding to existing plantings or through more intensive efforts to establish a larger native area. Pollinator habitat on the golf course includes existing out-of-play areas (such as buffer strips around water courses and bodies of water) and areas renovated specifically with pollinators in mind that include native plants, wildflowers, and flowering trees and shrubs. Out-of-play pollinator habitats have been shown to help nearly 50 species of pollinating insects (Dobbs and Potter, Golf Course Management). To convert existing out-of-play areas to a new native area, site preparation is key and may require more than one season of effort to reduce competition from invasive or other undesirable plants prior to planting. For more information on establishing a native area, see *Meadows and Buffers for Bees: Creating Mid-Atlantic Pollinator Habitat* and *Making Room For Native Pollinators*. For information on creating habitat specifically for monarch butterflies, a species in decline, see the Monarchs in the Rough website.

Figure 26. Monarch caterpillars feed exclusively on milkweed plants. Photo Credit: John Jacob.

Figure 27. Monarch butterflies feed and lay eggs on milkweed plants. Photo Credit: John Jacob.

Figure 28. Monarchs in the Rough is a new project specifically for golf courses to help provide habitat for monarchs. Photo Credit: John Jacob.

In addition to foraging habitat, pollinators require nesting sites. Providing nesting sites for native species can be accomplished by taking simple steps in out-of-play areas, such as:

- Leaving exposed patches of bare soil.
- Leaving dead trees, stumps, and posts.
- Planting hollow stem grass species.
- Providing stem bundles of hollow plant stems like bamboo.

- Creating bee blocks for solitary nesters such as mason and leafcutter bees.
- Creating artificial boxes for bumble bees.

A clean, reliable source of water is another essential habitat consideration for pollinators. Pollinators can use natural and human-made water features such as running water, pools, ponds, and small containers of water. Water sources should have a shallow or sloping side, so the pollinators can easily approach the water without drowning. In addition, irrigation management practices that preserve ground-nesting pollinators include irrigating at night and avoiding flooding any areas. Additional resources for selecting plants in Delaware to attract pollinators include the following:

- The Xerces Society recommended pollinator plants for the Mid-Atlantic Region: http://www.xerces.org/wp-content/uploads/2014/09/MidAtlanticPlantList_web.pdf
- The Pollinator Partnership Guide: *Selecting Plants for Pollinators, A Regional Guide for Farmers, Land Managers, and Gardeners in the Ecological Region of the Eastern Broadleaf Forest Oceanic Province*
- The Pollinator Partnership Guide: *Selecting Plants for Pollinators, A Regional Guide for Farmers, Land Managers, and Gardeners in the Outer Coastal Plain Mixed Province*

11.4 Managed Bee Hives on the Course

Hosting honey bee hives on the golf course provides bees with valuable green space, especially in urban areas and can be a positive public-relations tool. If embarking on this effort, consider:

- Partnering with an experienced local beekeeper. Proper beekeeping is time and knowledge intensive. If not partnering with an experienced beekeeper, then superintendents or other responsible staff should attend a beekeeping course. The Delaware Beekeepers Association may be able to provide additional assistance.
- Ensuring that enough food sources are available for both honey bees and wild pollinator species.
- Placing hives away from areas where golf course workers or golfers are active to avoid stings.
- Facing the hive exit in a direction away from in-play areas of the course.
- Educating golfers via explanatory signs, newsletters, and sales of honey and other bee products.
- Calling in an experienced beekeeper if disease or parasites are suspected in order to identify and mitigate any health issues.

The DriftWatch Specialty Crop Site Registry website allows beekeepers to register their hive locations. This site also has a new feature, BeeCheck, a specialized portal for beekeepers. This site now offers flags that may be used to increase the visibility of the hives. Information about this site and flags can be found at FieldWatch.com.

11.5 Pollinator Protection Best Management Practices

Pest Management Best Management Practices

- Before applying a pesticide, inspect the area for both harmful and beneficial insect populations, and use pesticides only when a threshold of damage has been indicated.
- Consider biological control agents, lures, baits, and pheromones as alternatives to insecticides for pest management.
- When pesticides are needed, select those with a lower impact on pollinators.
- If a granular formulation will control the pest, choose it over liquid formulations if honey bees are not in the vicinity Granular versions of pesticides are generally less hazardous to most bees, though honey bees may gather the granular version and pack into cells in hives.
- Restrict applications to early morning or evening when pollinators are not as active.
- Avoid applying pesticides during bloom season, and mow first to remove blooms, including those of flowering weeds such as white clover.
- Avoid application during unusually low temperatures or when dew is forecast.
- Use the latest spray technologies, such as drift-reduction nozzles to prevent off-site movement of pesticide.

Habitat Enhancement Best Management Practices

- Follow site preparation guidelines when renovating areas to ensure success.
- Choose south-facing sites whenever possible for establishing native areas.
- Place plants in masses (three or more) to attract pollinators.
- Select plants that feature different shapes, sizes, and colors and that bloom at different times of the year.
- Select native grasses that provide foraging and nesting habitat.
- Use both perennials and annuals.
- Leave stems and coarse, woody debris in native areas for pollinator nesting.
- Leave exposed patches of well-drained soil in native areas for pollinator nesting.
- Consider joining the Monarchs in the Rough project.
- Provide water sources with shallow sides for pollinators.

12 MAINTENANCE OPERATIONS

As part of the golf industry's responsibility to serve as an environmental steward, it is imperative that hazardous materials be handled, stored, recycled, and disposed in a safe, healthy, and sound manner. Pollution prevention includes the proper storage, handling, and disposal of chemicals, washwater, and wastewater. For example, washwater from pesticide application equipment must be managed as a pesticide. Conversely, wastewater not contaminated with harmful chemicals can be reused or discharged to a permitted stormwater treatment system. The "Pesticide Management" chapter discusses many maintenance operations-related BMPs specifically for pesticides. This chapter provides additional guidance for maintenance operations and points out differences between managing fertilizer equipment and pesticide equipment.

Facilities related to the storage and handling of pesticides, fertilizers, and other chemicals, especially in their concentrated form, pose the highest potential risk to water sources if accidentally released in quantity. Therefore, anyone storing, mixing, or loading potentially hazardous chemicals should treat all leaks, spills, and fires as emergencies and be prepared to respond to these emergencies promptly and correctly. For unintended releases of any chemicals, an emergency plan, spill kit, and first-aid kit should be readily available.

12.1 Regulatory Considerations

Pesticides and fertilizers used in the state must be registered with DDA. As discussed in the "Pesticide Management" chapter, the DDA regulates pesticides in Delaware under Title 3 Delaware Pesticide Rules and Regulations. Employees who handle pesticides must be trained in handling pesticides. Applicators must be certified. Local regulations may also be in place with respect to the siting of maintenance facilities.

DNREC's Underground Storage Tanks Section implements the Underground Storage Tank (UST) program. All USTs over 110 gallons storing petroleum are required to be registered with the state and must pay an annual registration fee. All registered USTs have to comply with Delaware Regulations Governing Underground Storage Tank Systems Regulations. For more information on UST compliance, see the DNREC's *Compliance Assistance Manual*.

DNREC compliance staff inspects UST systems every three years to verify that they are properly installed, inspected, tested, and maintained. The UST compliance program also requires that facilities demonstrate financial responsibility for taking corrective action caused by accidental releases from USTs. In addition, each UST facility must have a certified operator assigned to the site. More information on certification is available at the UST operator training webpage.

DNREC's Tank Management Section implements the Aboveground Storage Tank (AST) program. All registered ASTs must comply with Delaware's regulations governing Aboveground Storage Tanks. The AST program inspects AST systems to prevent releases to the environment by ensuring that AST systems are properly installed, inspected, tested, and maintained. Local regulatory authorities should be contacted as well before installing an AST.

DNREC's Emergency Prevention and Response Section includes the Emergency Response Group. This program provides around the clock response to emergency and non-emergency statewide petroleum and hazardous substance incidents to protect human health, safety, and the environment. In case of an incident requiring a response, DNREC's toll-free, 24-hour response line should be called at **1-800-662-8802.**

12.2 Storage and Handling of Chemicals

A well-designed and well-maintained chemical storage facility protects people from exposure, reduces the chances of environmental contamination, prevents damage to chemicals from temperature extremes and excess moisture, safeguards chemicals, and reduces the likelihood of liability. Proper handling and storage of pesticides and petroleum-based products are important to reduce risk of serious injury or death of an operator or bystander. Fires or environmental contamination may result in large fines, cleanup costs, and civil lawsuits if these chemicals are not managed properly. Pesticide-specific requirements and BMPs are provided in the "Pesticide Management" chapter.

12.3 Equipment Washing

Proper cleaning of equipment helps prevent residues from reaching surface waters, groundwater, drainage pipes, or storm sewers. The residues from washing equipment include grass clippings, soil, soaps, oil, fertilizers, and pesticides. Therefore, equipment washing should be conducted under controlled conditions in an appropriate contained area with minimal risk to the environment and to prevent adverse washwater and stormwater runoff impacts. Equipment washing guidelines and restrictions should be established that reduce the potential for pollutants to reach stormwater runoff, surface water or groundwater.

For equipment other than any with potential pesticide residue, the primary concerns related to washwater are the nutrients (N and P) associated with the clippings. To reduce the amount of organic debris in washwater, grass clippings should be blown off equipment with compressed air or backpack blower, instead of, or prior to, washing with water (Figure 29). The best practice is to have a dedicated wash area with a catch basin to collect remaining grass clippings (Figure 30). Clippings can be collected and then composted or removed to a designated debris area (Figure 31). When formal washing areas are not available, a "dog leash" system using a short, portable hose to wash off the grass at random locations may be an option. However, these locations should not be near surface waters, wells, or storm drains.

For equipment with possible pesticide residue, BMPs should be followed to ensure that washwater does not become a pollution source. Captured washwater can be used as a dilute pesticide per label, or it may be pumped into a rinsate storage tank for use in the next application and used as a dilute pesticide per the label. See the "Pesticide Management" chapter for more information.

Figure 29. Blowing off clippings from a mower prior to washing is an important BMP for reducing nutrient enrichment of washwater. Photo Credit: Erik Ervin.

Figure 30. Collected clippings in the wash area will be removed to a composting area elsewhere on the facility. Photo Credit: Erik Ervin.

Figure 31. Clippings should be separated from wash water and composted. Photo Credit: Erik Ervin.

12.4 Equipment Storage and Maintenance

Like chemical storage facilities, equipment storage and maintenance facilities should be designed to prevent the accidental discharge of chemicals, fuels, or contaminated washwater from reaching water sources. Properly storing and maintaining equipment also extends the useful life of machines and reduce repairs.

12.5 Fueling Facilities

Fueling areas should be properly sited, designed, constructed, and maintained to prevent petroleum products from being released into the environment through spills or leaks. Regulations and compliance issues differ depending on whether facilities use ASTs or USTs. Aboveground tanks are easier to monitor for leaks and are therefore the preferred storage method. Because of the potential for groundwater contamination from leaking USTs, leak detection monitoring is a critical aspect of UST compliance (Figure 32). For further information on compliance, see DNREC's *Compliance Assistance Manual*. Any leaks or spills must be contained and cleaned immediately. If any potential for petroleum contamination occurs from either an AST or UST, DNREC's toll-free, 24-hour response line should be called at **1-800-662-8802.** DNREC also oversees cleanup of above ground and underground storage tank sites.

Fueling areas should be sited on impervious surfaces, equipped with spill containment and recovery facilities, and located away from surface waters and water wells (Figure 33). Catch basins in fueling areas should be directed toward an oil/water separator or sump to prevent petroleum from moving outside any containment structure. Floor drains in fueling areas should be eliminated unless they drain to containment pits or storage tanks.

Figure 32. Monitoring system for an underground fuel storage tank. Photo Credit: Erik Ervin.

Figure 33. Fueling area includes fire suppression equipment and spill materials (yellow storage area). Photo Credit: Erik Ervin.

12.6 Waste Handling

Facilities need to regularly review how they handle the disposal of unwanted, expired, or accumulated items, including chemicals, paints, pesticides, tires, batteries, used oils, solvents, paper products, plastic or glass containers, and aluminum cans. Developing recycling programs reduces waste and minimizes the quantity of waste reaching landfills; for example, steel and

cardboard can be easily recycled (Figure 34). In some cases, recycling of some wastes may be required locally. Superintendents should be aware of these requirements.

Figure 34. Steel and aluminum recycling at Deerfield. Photo Credit: John Jacob.

All packaging from chemicals, their containers and other wastes should be properly disposed of. Pesticide-specific waste handling requirements are identified on the pesticide label and are discussed in more detail in the "Pesticide Management" chapter.

12.7 Emergency Preparedness and Spill Response

Enough absorbent material must be available to handle a spill of the largest container in storage. Sorbent materials include booms, socks or mini booms, pillows, pads and rolls, and loose sorbents. These sorbent materials may be universal or more specific (such as for petroleum products). A spill kit is a necessity at any facility where pesticides and other chemicals are used or stored.

In Delaware, DNREC's Division of Waste and Hazardous Substances responds to and investigates accidents/incidents related to environmental spills and other emergencies, and oversees cleanup to protect human health, safety and the environment. DNREC should be contacted immediately if any release is not contained and controlled (1-800-662-8802 or 302-739-9401). Local officials should need to be notified as well. If the spill constitutes a reportable quantity, the EPA's National Response Center (800-424-8802) must also be notified. All contact information and reporting requirements should be identified in the emergency plan.

For more information on emergency planning and response to unintended releases see:

- Chapter 9 "Emergency Planning." Maryland Pesticide Applicator Core Manual, pp. 137-147.
- Pesticide Information Leaflet No. 16: Handling Pesticide Spills. 2013. University of Maryland.

Host a tour for local emergency response teams (e.g. firefighters) to show them the facility and to discuss the emergency response plan. Seek advice on ways to improve the plan.

12.8 Maintenance Operations Best Management Practices

Storage and Handling of Chemicals Best Management Practices

- Post warning signs on chemical storage buildings, and especially near any entry or exit areas.
- Storage facilities must be secured and allow only authorized staff to have access.
- Pesticide and fertilizer storage areas should preferably be located away from other buildings.
- Floors should be sealed with chemical-resistant paint.
- Floors should have a continuous sill to help contain any spills.
- Install a fire suppression system or equipment.
- Shelves should be made of plastic or reinforced metal. Metal shelving should be coated with paint to avoid corrosion. Wood should not be used due to its ability to absorb spilled chemicals.
- Exhaust fans and an emergency wash station should be provided.
- Light and fan switches should be installed to illuminate and ventilate the building.
- Store chemicals in original containers.
- Store chemicals so that the label is clearly visible. Loose labels should be refastened.
- Store flammable chemicals separately from non-flammable chemicals.
- Store liquid materials below dry materials to prevent contamination from a leak.
- Use regulatory agency-approved, licensed contractors for the disposal of chemicals.
- Provide adequate staff training pertaining to the risks and liabilities of chemical storage and use.
- Train staff how to access and use the facility's SDS database.
- Maintain accurate inventory lists.

Equipment Washing Best Management Practices

- Brush or blow off accumulated grass clippings from equipment using compressed air or backpack blower before washing.
- Wash equipment on a concrete pad or asphalt pad that collects the water. After the collected material dries, collect and dispose of it properly.
- Washing areas for equipment not contaminated with pesticide residues should drain into oil/water separators before draining into sanitary sewers or holding tanks.

- Do not wash equipment used to apply pesticides on pads with oil/water separators. Do not wash near wells, surface water, or storm drains.
- Use spring-loaded spray nozzles to reduce water usage during washing.
- Minimize the use of detergents. Use only biodegradable, non-phosphate detergents.
- Use non-containment washwater for field irrigation.
- Do not discharge non-contaminated wastewater during or immediately after a rainstorm, since the added flow may exceed the permitted storage volume of the stormwater system.
- Do not discharge washwater to surface water, groundwater, or susceptible/leachable soils either directly or indirectly through ditches, storm drains, or canals.
- Never discharge to a sanitary sewer system without written approval from the appropriate entity.
- Never discharge to a septic tank.
- Do not wash equipment on a pesticide mixing and loading pad. This keeps grass clippings and other debris from becoming contaminated with pesticides.
- Solvents and degreasers should be used over a collection basin or pad that collects all used material.

Equipment Storage and Maintenance Best Management Practices

- Store equipment in areas protected from rainfall. Rain can wash residues from equipment and potentially contaminate the surrounding soil or water.
- Perform equipment maintenance activities in a completely covered area with sealed impervious surfaces.
- Drains should either be sealed or connected to sanitary sewer systems with the approval of local wastewater treatment plants.
- Solvents and degreasers should be stored in locked metal cabinets away from any sources of open flame.
- Complete a chemical inventory and keep SDS of each on-site. A duplicate set of SDS should be kept in locations away from the chemicals, but easily reached in an emergency.
- Use PPE when working with solvents.
- Use containers with dates and contents clearly marked when collecting used solvents and degreasers.

Fueling Facilities Best Management Practices

- Aboveground fuel tanks are preferred as they are more easily monitored for leaks as compared with underground tanks.
- Fueling stations should be located under roofed areas with concrete pavement whenever possible.
- Fueling areas should also have spill containment and recovery facilities located near the stations.
- Develop a record-keeping process to monitor and detect leakage in USTs and ASTs.
- Visually inspect any AST for leakage and structural integrity.

- Secure the fuel storage facilities and allow access only to authorized and properly trained staff.
- Ensure that fuel tanks and pumps are properly labeled.
- Post no smoking signs near fueling facilities.

Waste Handling Best Management Practices

- Label containers for collecting used solvents, oils, and degreasers.
- Recycle lead-acid batteries. If not recycled, batteries are classified as hazardous waste.
- Store old batteries on impervious surfaces in areas protected from rainfall.
- Recycle used tires, paper products, cardboard, plastic or glass containers, steel, aluminum cans, and used solvents, oils, and degreasers.
- Provide a secure and specifically designated storage for the collection of recyclable waste products.
- Recycle or properly dispose of light bulbs and fluorescent tubes.
- Complete annual Tier II reporintg requirement and file with the Delaware's State Emergency Response System.

Emergency Preparedness and Spill Response Best Management Practices

- Develop a golf course facility emergency response plan that includes procedures to control, contain, collect, and store spilled materials.
- Prominently post "Important Telephone Numbers," including the hotline number for DNREC (1-800-662-8802) for emergency information on hazards or actions to take in the event of a spill.
- Ensure an adequately sized spill containment kit is readily available.
- Designate a spokesperson who will speak on behalf of the facility should an emergency occur.

13 LANDSCAPE

The fundamental principle for the environmentally sound management of landscapes is "choose the right plant, in the right place." Ideal landscape plants are native and adapted specifically to the soil, degree and direction of slopes, precipitation type and amounts, wind direction and speed, light patterns, and microclimate. Susceptibility to major damage by insects and other pests is another selection criterion, as are the nutrient levels of the area. By using native or adapted plants that mimic natural ecosystems, landscapes that are designed for the specific location, management capabilities and desired style can reduce overall management inputs, attract pollinators, provide multi-season interest, and enhance out-of-play areas.

Figure 35. Landscaped beds at Deerfield. Photo Credit: John Jacob.

13.1 Planning and Design

Planning begins with a careful assessment of existing conditions. Slopes and drainage patterns impact not only the playability of the course, but the survival of existing and proposed plants. A majority of the non-play areas on the golf course should remain in natural cover. Supplemental planting of native or adapted trees, shrubs, and herbaceous vegetation can enhance the habitat of wildlife, including non-game species, birds, and pollinators, in non-play natural areas. Supplemental planting can also limit soil erosion and protect stream banks. Mimicking natural ecosystems by leaving dead trees (snags), brushy understory plants, and native grasses and forbs in these areas also reduces maintenance work by minimizing or eliminating the need to mow or apply fertilizer or pesticide.

Designs for higher-impact, higher-use landscape areas, such as around the clubhouse, should utilize natural drainage patterns and channel runoff away from impervious surfaces (e.g. paved areas), conserve water, and lower the nutritional input requirements once mature. Installing rain gardens in locations where they catch and temporarily hold water (such as near roofs and other impervious surfaces) helps control stormwater runoff, remove contaminants before releasing water into the surrounding soil or aquifer, and conserve water by reducing supplemental irrigation needs. For more information on rain gardens, see the University of Delaware Cooperative Extension publication *Rain Gardens*.

Golf courses are excellent facilities for zoning the landscape with designations of high-impact zones, transition zones, and perimeter zones, and for matching high-use and high-impact areas to plants and landscape styles that need more intense management.

13.1.1 High-use and High-impact Zones

In high-use and high-impact zones, the design intent is to create highly ornamental, garden-like landscapes based primarily on visual impact and functionality, not necessarily related to the colors, patterns, and cycles of the native Delaware landscape. If site conditions are suitable and aesthetic requirements are met, regional flora should be given preference. There will be an elevated level of intervention and maintenance, sufficient to create and maintain a highly ordered aesthetic attractive on a small to medium scale, and evident even when viewed at close range. Such designs rely on well-defined groupings and masses to create ornamental impact based upon qualities of color, texture, and form. This approach is appropriate for small- to medium-scale sites where the desire for a neat, highly ornamental appearance exceeds the capacity of the native and regional flora, and/or where the cultural conditions on the site are so heavily affected they severely limit the choice of native or regional species. It is appropriate in areas where the Delaware native flora is a minimal or nonexistent part of the local context. Well-defined, small-scale, high-visibility sites such as the clubhouse landscape and parking lot traffic islands are examples of high-use and high-impact zones. In such zones, these steps are recommended:

- Remove existing vegetation completely, expect for desirable specimens, which may be retained.
- Correct and maintain environmental conditions to facilitate plant growth. Such changes may include tillage, soil amendment, soil replacement, or modification of topography and drainage.
- Select the plant palette for multiple seasons of interest, resulting in plantings that are neat and attractive on a small scale.
- Select plants based on their ability to survive drought, full sun, wind, salt, or other cultural extremes as much as possible within the design parameters.
- Invest more in plant material to create immediate impact.
- Weed routinely.
- Provide supplemental watering whenever conditions would negatively impact the visual effectiveness of the planting.
- Use mulch as a typical ground layer.

13.1.2 Transition Zones

The design intent in transition zones features ornamental landscapes inspired by the regional colors, patterns, and cycles of the native Delaware landscape, but is not necessarily based on plant community dynamics. These areas require a moderate level of intervention, sufficient to create and maintain an aesthetic order that is noticeable and attractive on a medium to large scale. The designs rely on well-defined groupings and masses to create ornamental impact, using regional plant associations when practical to suit this purpose.

This approach is appropriate for medium- to large-scale sites where cultural conditions are suitable, or suitable with moderate modifications, for a mix of Delaware and North American native species. This approach also works for moderate installation and maintenance budgets. It is appropriate in areas where the Delaware native flora is a modest to minimal part of the local context. Transition zone landscaping may occur on the course at tees or key junctions of paths. Creating transition zones can include these steps:

- Selectively or completely remove existing vegetation. In some cases, the existing vegetation can be left as the ground layer.
- Correct and maintain environmental conditions to facilitate plant growth, which may include soil modifications (e.g. change pH).
- Select the plant palette for multiple seasons of interest that match regional cycles, organized on a medium to large scale.
- Restrict plants to species that tolerate drought, full sun, wind, salt, or other cultural extremes.
- Spot control aggressive weeds on a regular basis to supplement plant competition as the primary method of weed control.
- Provide supplemental watering during establishment and only in extreme drought conditions.
- Use mulch around planted specimens as needed, but the long-term ground layer will develop from seeded, planted, or existing vegetation.

13.1.3 Perimeter Zones

The design intent is to develop attractive, naturalistic landscapes based directly on the regional ecology: the dynamics, patterns, colors, and cycles of Delaware's native plant communities. A minimal level of intervention is required for these areas, just sufficient enough to create and maintain an aesthetic order that can be appreciated on a large scale. Though not intended to fully replicate native plant communities, regional plant associations and dynamics are conserved and enhanced. The low level of intervention allows for considerable natural growth and propagation of native plant species on site.

This approach is appropriate for large-scale sites where cultural conditions are suitable, or suitable with minor modification, for Delaware native species, and where the installation and maintenance budget is minimal. It is particularly appropriate in areas where the Delaware native flora remains

a significant part of the local context. This perimeter zone approach should be used in landscaped areas throughout the remainder of the course. Here are key steps to take in perimeter zones:

- Selectively remove existing vegetation to introduce aesthetic order or remove highly undesirable species. The existing vegetation is rarely completely removed.
- Only minimal modifications of environmental conditions are employed. Topography may be modified to provide sites conducive the growth of regional vegetation.
- Select the plant palette to complement the surrounding vegetation in terms of patterns, color, and cycles. Select plants based in their likelihood to thrive in the existing conditions, with an understanding and awareness of site ecology and opportunities provided by cultural niches.
- Restrict plant selection to species that tolerate drought, full sun, wind, salt, or other cultural extremes.
- Plant competition from desirable species is the primary method of weed control, but spot control of aggressive species that threaten the long-term survival of the site is also practiced.
- Provide supplemental watering during establishment only.
- Use mulch around planted specimens as needed, but the long-term ground layer will develop from seeded, planted, or existing vegetation.

13.2 Site Inventory and Assessment

Before developing a landscape plan, conduct an inventory of existing plants, their condition and quality, their contribution to the overall style of the course, and how they've been managed. For landscaped areas, conduct a soil analysis and a soil test. The soil analysis evaluates the structure and texture of the soil. If needed, soil amendments can improve the structure and texture of soil, increase its water-holding capacity, and reduce nutrient leaching. Soil amendments, such as landscape waste compost, can contribute to an overall healthier plant environment, allowing easier root development and fewer soil-related problems. Do not use peat moss as an amendment as it is both expensive and originates from peat bogs, which are non-renewable. Apply fertilizers based on the results of a soil test as described in the "Nutrient Management" chapter of this document.

13.3 Plant Selection

Select plants for landscape planting that grow in natural ecosystems in the area, especially in the perimeter zones and out-of-play areas (see zone descriptions in Section 13.1). Native plants provide food and cover for native insects, birds, and other game and non-game wildlife. As land becomes developed, it is even more important to provide habitat and other ecosystem services (fresh water, clean air, carbon sequestration, etc.) in open, managed areas like golf courses. Golf courses have the opportunity to teach sustainable landscape design principles to players if responsible landscaping practices are appropriately modeled.

Native plant species also provide wildlife with habitat and food sources, such as native flower areas that benefit pollinators. After establishment, site-appropriate plants normally require little to no irrigation.

Consider design intentions, ultimate sizes and growth rates of trees, shrubs, and ground covers when selecting and placing landscape plant. This reduces the need for future pruning and debris removal. In addition, the adaptability of plants to a specific site is important. Site-specific characteristics to consider include sun exposure, light intensity, wind conditions, drainage, and temperatures.

For recommended plant species in Delaware, see:

- *Plants for a Livable Delaware*. UD Extension.
- *Livable Plants for the Home Landscape*. UD Extension.
- *Native Plants for Delaware Landscapes*. University of Delaware Botanic Garden.
- *Trees for Delaware*. UD Extension.
- *Tree Selection Guide.* UD Extension.
- *Livable Ecosystems: A Model for Suburbia*. UD Extension.
- Certified Wildlife Habitats program. Delaware Nature Society.
- *Plant Selection for Water Conservation*. UD Extension.
- *Delaware Native Plants for Communities in Kent and Sussex Counties*. Delaware Nature Society.
- Native Plant Finder. Mt. Cuba Center.
- *Native Plants for Wildlife Habitat and Conservation Landscaping/Chesapeake Bay Watershed*. U.S. Fish & Wildlife Service.
- Avoid the introduction of invasive or potentially invasive plants. Control invasive or noxious weed species present on the site. The Delaware Invasive Species Council provides lists of invasive species. The state's noxious weed list is managed DDA.

13.4 Installation

During landscape bed construction, use native soil and break up any remaining hardpan or compaction from construction. Slope beds away from buildings, with a minimum percent slope of 2 percent for at least 10 feet. Resolve drainage issues and establish clear drainage patterns prior to installing plants. Install plants with higher moisture requirements at lower elevations and drought-tolerant plants at higher elevations.

In general, the best times to plant trees and shrubs in Delaware are in early spring (March through early May) or in the fall (mid-August through October). These times reduce the stress on the plants by capitalizing on periods of cooler (but not cold) temperatures and increased moisture. However, many evergreens perform best if planted only in spring unless highly

managed during establishment. Install herbaceous plants in late spring or earlier in fall to give these smaller plants a better chance to establish good root systems. Additional guidelines for planting in Delaware can be found in *Landscape Management* and *Trees for Delaware*.

13.5 Irrigation

Regardless of their ability to tolerate drought, all plants require supplemental irrigation during establishment. To increase water-use efficiency and improve plant establishment in landscaping, consider hand-watering individual plants for the first several months of the growing season. When it's needed, water plants in the early morning to conserve water and avoid water loss due to evaporation. Water new trees and shrubs at least once a week to a depth of one foot and more frequently during dry weather. When using a hose, allow the water to trickle out for at least an hour, and move the hose several times around the base of the tree. Watering bags are effective tools for applying water slowly. Apply at least five gallons when watering from a container, pouring it slowly over the back of a shovel to spread the water. Keep trees well-watered throughout the entire establishment period (one year or more depending on the caliper) with deep, slow watering.

If trees and shrubs are planted in an area with an existing irrigation system, assess the coverage to determine whether changes should be made to identify areas where efficiency can be improved. Carefully assess landscape watering patterns to minimize spray on impervious surfaces, blockage of spray by plants or other obstructions, and runoff on slopes, clay soils, or compacted sites. Focus on the irrigation of woody plants at or beyond the dripline to promote extensive rooting. Periodically throughout the growing season, check the performance of the landscape irrigation system.

13.6 Use of Mulch

Mulch conserves soil moisture, mitigates temperature extremes, and reduces weed competition. During the growing season, mulch also serves as a visual reminder to keep mowers and string trimmers away from shrub stems and tree trunks. In winter, mulch helps prevent soil cracks from forming and exposing roots to cold temperatures and winter desiccation. Organic mulches include herbicide-free grass clippings (though avoid applying too deeply to avoid matting and heating the soil), shredded bark, bark chunks, composted sewage sludge, one-year-old wood chips, pine needles and composted, shredded leaves. Organic mulches are preferred, as non-organic mulches such as stone may add heat stress around annuals and perennials.

Annuals and perennials grow best with no more than 2 inches of mulch. Around trees and shrubs, mulch should be no more than 3 inches deep. With any planting, place mulch between the plants and not on top of the crown or against tree trunks or shrub canes. In the winter after the ground freezes, a deeper layer of coarse mulch (evergreen branches) over bulbs and other perennials can delay or prevent early growth and can be used to protect tender plants. Do not place a new layer

of mulch over the old layer each year. Each spring, rake the old mulch to break up any hard crest and add only enough new mulch to maintain a 2-inch to 3-inch layer.

13.7 Pruning

Correctly pruning trees, shrubs, and herbaceous perennials has multiple benefits throughout a landscape or golf course. Trees and shrubs are pruned first for safety. Pruning in some cases can increase plant health and result in better growth in future seasons. Typically, the ideal time to prune deciduous shade trees in Delaware is February to March, except in times of drought. Shrubs should be pruned based on their season of bloom (if the flowers are significant). Plants that bloom on second-year or old wood set their flower buds immediately after flowering and can be pruned for the month following bloom. Plants that bloom on new wood, or current-season wood, can be pruned in early spring prior to dormancy break. For more information on pruning, see:

- *Trees for Delaware*. Delaware Cooperative Extension.
- *Pruning Evergreens*. Delaware Cooperative Extension
- *Pruning Woody Plants*. Delaware Cooperative Extension

13.8 Pest Management

The same principles and methods identified in the IPM chapter of this document can be applied to landscaped areas. The following publications provide guidance specifically for these areas:

- What is Integrated Pest Management (IPM)? Delaware Cooperative Extension.
- Beneficial Insects (The Good Guys). Delaware Cooperative Extension.
- Garden Pests and Diseases. Delaware Cooperative Extension.
- Ornamentals Hotline newsletter. Delaware Cooperative Extension.

The Plant Diagnostic Clinic at the University of Delaware accepts plant samples showing signs or symptoms of disease. Visit the Plant Diagnostic Clinic website for more information on submitting samples. In addition, the University of Delaware's Hot Topics in Plant Health blog provides links to timely plant-related information.

13.9 Landscape Best Management Practices

Planning and Design Best Management Practices

- ❖ Leave the majority of non-play areas -- the perimeter zone -- in natural vegetation.
- ❖ Enhance natural areas with supplemental plantings of native and adapted species.
- ❖ In landscaped areas, use natural drainage patterns and directional site grading to channel runoff away from impervious surfaces onto planted areas such as grass swales, filter strips, or rain gardens.
- ❖ Install rain gardens in locations where they can catch and temporarily hold runoff.

- Minimize the amount of area covered by paved surfaces. Where feasible, use permeable materials such as bricks laid on sand, interlocking pavers or pervious pavers, porous concrete, mulch, or plants.

Site Inventory and Assessment Best Management Practices

- Conduct an inventory of existing plants, their condition and quality, and their contribution to the overall style of the course.
- Conduct a soil analysis before choosing specific plants for landscape areas.
- Conduct a soil test before applying fertilizers. Modify pH if needed, based on soil test results.
- Amend the soil to improve soil texture and increase water infiltration.

Plant Selection Best Management Practices

- Select native species whenever possible; use adapted species or cultivars of native plants where appropriate.
- Select trees, plants, and grass species to attract birds and pollinators seeking wild fruits, herbs, seeds, nesting materials, cover, and insects.
- Know the ultimate sizes and growth rates of trees, shrubs, herbaceous plants, and ground covers.
- Select plants recommended for your specific location in Delaware.
- Choose the most stress-tolerant species for a particular area.
- Do not introduce invasive species into the landscape.
- Control or remove existing invasive species and noxious weeds.

Landscape Irrigation Best Management Practices

- Irrigate frequently during establishment.
- Water established plants based on their needs and, when needed, deeply and infrequently.
- Irrigate in the early morning to conserve water.
- Avoid water runoff onto impervious surfaces or slopes.
- Evaluate landscape irrigation performance periodically.

Mulching Best Management Practices

- Use mulch in landscaped beds.
- Use organic mulches whenever possible.
- Use only herbicide-free grass clippings when using grass clippings as mulch.
- Protect bulbs and other perennials in winter with a layer of coarse mulch (evergreen branches) to delay or prevent early growth.

Pruning Best Management Practices

- Hire a certified arborist to prune trees as the correct pruning cuts are essential to good tree health.
- Maintain pruning equipment to ensure clean cuts and less risk of damage to the plant.
- Prune deciduous shade trees in late winter (February to March), except in times of extreme drought.
- Prune shrubs based on their season of bloom.

Pest Management Best Management Practices

- Use IPM for landscaped areas.

14 ENERGY

Golf courses use a variety of energy sources, primarily fossil fuel based (e.g. coal-generated electricity, gasoline, diesel). However, renewable sources, such as solar, wind, and geothermal are increasingly being utilized and can provide a return on investment as well as increasing sustainability efforts at the facility.

To establish effective energy BMPs, the facility's existing energy consumption should be evaluated, and goals set for energy reduction, conservation, and incorporation of new energy-saving technologies. Many energy-related BMPs overlap with other facility-related BMPs. For example, improving irrigation efficiency also reduces energy consumption. Having an efficient and well-maintained system, upgrading to a variable speed pump if/when possible, and reducing irrigation water consumption all reduce overall facility energy consumption.

14.1 Energy Audits and Evaluation

Increasing energy efficiency can decrease operating costs and reduce energy consumption. The first step in improving energy efficiency is to identify areas most in need of energy conservation through an energy audit. State agencies and local utilities can provide information and support for energy evaluation efforts. For example, DNREC offers Energy Assessment Grants, that can assist in evaluating appropriate, cost-effective energy efficiency improvements. DNREC also offers both grants and low-interest loans to support energy efficiency projects. Both are funded through the state's Energy Efficiency Investment Fund (EEIF).

A thorough energy audit should:

- Evaluate insulation in heated buildings.
- Evaluate heating, ventilation, and air conditioning (HVAC) system efficiency.
- Determine annual energy usage.
- Itemize usage according to various categories.
- Determine if energy usage during non-peak hours is maximized.
- Compare usage with similar small businesses.
- Identify areas of improvement.

The results of an energy audit can be used to establish an environmental plan and to set energy conservation goals. An energy management plan sets a baseline related to current energy use and incorporates quality management elements (plan, do, check, and act) for continual improvements. Once goals for energy conservation are established and documented, this policy should be communicated to all staff.

Evaluating the performance of an energy conservation program requires tracking and measuring energy use at the facility based on energy assessment units (e.g. kilowatt hours or BTUs). Monitoring energy usage can be accomplished with energy management software or programs such as the EPA's Portfolio Manager, which also incorporates features such as reporting, savings

calculations, and carbon footprint calculations. To benchmark performance, energy consumption can be compared with other local golf facilities of similar size or more generally to buildings of similar size.

14.2 Energy Efficiency Improvements

Energy efficiency improvements vary widely from opportunities to build/renovate buildings adhering to Leadership in Energy and Environmental Design (LEED) standards to simple and much less expensive improvements such as installing programmable thermostats and low-flow faucets. The energy audit results, energy conservation goals, and the available budget will help prioritize improvements over time.

14.3 Green and Alternative Energy

Green and alternative energy can be incorporated into golf course operations. Golf courses can become small-scale generators of energy through wind, solar, and photovoltaic installations, as well as geothermal heating and pumping. Golf courses normally have the land, space, and natural resources available on the property to lend themselves to energy generation as newer technologies become more affordable.

Some policies, financial incentives, and loan opportunities exist at the state and local level for renewables and energy efficiency measures at commercial enterprises such as golf courses. State agencies and energy providers can provide information, expertise, and incentives to help achieve these goals. For more information, see the Delaware Renewable Energy Assistance program web page.

14.4 Energy Best Management Practices

Energy Audits and Evaluation Best Management Practices

- Conduct an energy audit, including lighting, insulation, and HVAC systems.
- Monitor energy use by tracking statistics and “time of use” data.
- Install precision meters, gauges, etc.
- Develop an equipment inventory that documents individual equipment’s energy use, traffic patterns, maintenance records, operation hours, etc.
- Benchmark performance against similar-sized facilities.
- Evaluate and monitor all energy sources, tracking both costs and any usage trends.
- Educate, train, and motivate employees on energy efficiency practices pertaining to golf course operations.

Energy Efficiency Improvements Best Management Practices

- Consider pursuing the U.S. Green Building Council’s LEED certification for new buildings and existing building retrofits.

- Add insulation where needed.
- Use non-peak electrical hours for charging golf carts and maintenance equipment.
- Prioritize pump station usage during non-peak hours.
- Upgrade irrigation systems to variable speed pumps.
- Limit high-consumption activities when demand is high.
- Install LED lighting and other high-efficiency alternatives.
- Install motion sensors for lights where appropriate.
- Install low-flow faucets.
- Install programmable thermostats.
- Consider energy management software.
- Utilize the EPA's Energy Star and Portfolio Manager programs.
- Utilize the EPA's WaterSense program.
- Prioritize energy consumption as part of decision-making when making purchases concerning all aspects of facility management.
- Evaluate effectiveness of upgrades according to efficiency and conservation goals for energy use.

Green and Alternative Energy Best Management Practices

- Use alternative energy from natural sources, such as solar, geothermal, and wind energy generation when possible.
- Assess the viability of small-scale wind, solar, and photovoltaic installations.
- Install geothermal heating and cooling systems.
- Install solar/geothermal pumps for pools and spas.

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