Best Management Practices for Maryland Golf Courses

AUGUST 2017

Acknowledgements

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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.

Others

Funding and support for this project also provided by the Maryland State Golf Association, the Mid Atlantic Section of the Professional Golfers Association, and the Mid-Atlantic Golf Course Owners Association.

Acronyms

ABW	annual bluegrass weevil
BMP	Best Management Practice
Ca	calcium
CEC	cation exchange capacity
CMC	chemical mixing center
COMAR	Code of Maryland Regulations
DO	dissolved oxygen
DU	Distribution Uniformity
EPA	Environmental Protection Agency
ESD	environmental site design
ET	evapotranspiration
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FRAC	Fungicide Resistance Action Committee
HOC	height of cut
HRAC	Herbicide Resistance Action Committee
IBDU	isobutylidene diurea
IPM	integrated pest management
IRAC	Insecticide Resistance Action Committee
K	potassium
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MES	Maryland Environmental Service
Mg	magnesium
mg/L	milligrams per liter
MSDS	Material Safety Data Sheets
N	nitrogen
NH^{+}_{4}	ammonium
NO^{-}_{3}	nitrate
NRC	National Response Center
NTEP	National Turfgrass Evaluation Program
OSHA	Occupational Safety and Health Administration
P	phosphorus
PCU	polymer coated ureas
PGR	plant growth regulator
PPE	personal protective equipment
QA/QC	quality assurance/quality control
SCU	sulfur coated urea
SDS	Safety Data Sheets
TMDL	Total Maximum Daily Load
UF	ureaformaldehyde
USGA	United States Golf Association
VFD	variable frequency drive
VGCSA	Virginia Golf Course Superintendents Association
WAP	Water Appropriation Permit

Definitions

Best Management Practices: 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.

Drift: The physical movement of pesticide droplets or particles through the air at the time of pesticide application or soon thereafter from the target site to any non- or off-target site. (Environmental Protection Agency definition)

Integrated Pest Management: 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. (Definition from Maryland Pesticide Applicator Core Manual. National Association of State Departments of Agriculture Research Foundation.)

Leaching: Transport of water-soluble plant nutrients or chemicals from the soil as water moves through the soil profile and into the saturated zone.

Littoral Shelf: Shallow areas (typically 1-2 feet in depth) within the near shore area of a lake or pond. Littoral shelves provide emergent aquatic vegetation the appropriate water depth necessary to thrive

Nonpoint Source: Pollution not originating from a discrete location; comes from many different sources including land runoff, precipitation, atmospheric deposition, drainage, seepage, or modifications to natural waterways.

Riparian Buffer: The aquatic ecosystem and the portions of the adjacent terrestrial ecosystem that directly affect or are affected by the aquatic environment. This includes streams, rivers, lakes, bays and their adjacent side channels, floodplain, and wetlands. (Definition from U.S. Department of Agriculture.) Natural riparian buffers are composed of grasses, trees, or both types of vegetation.

Runoff: Water flow along the ground's surface that can pick up contaminants, such as fertilizers and pesticides. Runoff occurs when the soil is saturated, compacted, high in clay particles, or has lost soil structure (large pores).

Sedimentation: The transport of soil particles (sediment) in runoff that are deposited into surface waters.

Stormwater: Water that originates as some form of precipitation, either rainfall or snowmelt.

Tidal Wetlands: From the State of Maryland (Tidal Wetlands Act; Natural Resources Article, Annotated Code of Maryland Regulations), "tidal wetlands" are defined as "all State and private tidal wetlands, marshes, submerged aquatic vegetation, lands, and open water affected by the

daily and periodic rise and fall of the tide within the Chesapeake Bay and its tributaries, the coastal bays adjacent to Maryland's coastal barrier islands, and the Atlantic Ocean to a distance of 3 miles offshore of the low water mark.”

Wetlands/Nontidal Wetlands: From the State of Maryland (Nontidal Wetlands Act; Natural Resources Article, Code of Maryland Regulations), "nontidal wetlands" are areas meeting the following conditions: "(a)...an area that is inundated or saturated by surface water or ground water at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions, commonly known as hydrophytic vegetation; (b) is determined according to the Federal Manual; (c) does not include tidal wetlands regulated under Natural Resources Article, Title 9, Annotated Code of Maryland."

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Introduction

Maryland'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 Maryland turf scientists to develop and document best management practices (BMPs) for golf course management. These research-based, voluntary guidelines developed specifically for the state of Maryland, 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 community at large, 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 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 Maryland'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.

Key Components of Maryland'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 Maryland 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.

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.

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.

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.

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.

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; some sources, such as the University of Maryland's nutrient management guidelines, are updated regularly and 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 (http://www.marylandgolfbmp.org) is also a resource for identifying these changes.

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.

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.

Wetlands

During the planning phase, the boundaries of any tidal or nontidal wetlands[1] or 100-year floodplains on the site must be identified because activities taking place within these boundaries require permits. The Maryland Department of the Environment's (MDE) Wetlands and Waterways Program protects such waterbodies from loss and degradation. This protection is achieved through the regulation of the draining, dredging, and filling of tidal and nontidal wetlands, of the nontidal wetland buffer, and of waterways, including the nontidal 100-year floodplain. The regulations include a permitting or authorization process implemented in close coordination with the federal government, specifically the Army Corps of Engineers.

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 a wetland or the addition of fill materials to a state-regulated wetland or waterway. All state regulations that pertain to wetlands are provided by MDE in a wetlands regulation database.

Floodplains

Any activity associated with construction or renovation, including grading and filling, within the 100-year floodplain zone (nontidal or tidal) requires a permit issued by the local regulatory authority (county or town) in keeping with local ordinances. A Model Floodplain Management Ordinance, which meets all state and federal regulations and contains recommendations for improved management of floodplains, has been adopted widely by communities in Maryland. 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 MDE's Floodplain Permitting page.

[1] See the Definition section for Maryland's definitions of tidal and nontidal wetlands.

Erosion and Sediment Control

MDE has implemented a statewide erosion and sediment control program to control sediment-laden runoff from land-disturbing activities in accordance with Code of Maryland Regulations (COMAR) 26.17.01, the 2011 Maryland Standards and Specifications for Soil Erosion and Sediment Control handbook, and the Stormwater Management Act of 2007. MDE's regulations establish criteria and procedures for erosion and sediment control throughout Maryland. These regulations enhance erosion and sediment control practices, improve the water quality of construction site runoff, and help in Chesapeake Bay restoration efforts. The handbook serves as the official guide for erosion and sediment control principles, methods, and practices. Each county and municipality, in turn, is required to adopt an erosion and sediment control ordinance that meets the intent of Maryland's sediment control laws and regulations.

Listed Species

In addition to identifying any 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 Maryland Department of Natural Resources' Natural Heritage Program.

Planning

Proper planning will minimize 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.

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 that is 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

Proper design will meet the needs of the stakeholders, protect the location’s environmental resources, include site-appropriate drainage features, and be 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 chapter on "Surface Water Management," the Cultivar Selection section of the "Cultural Practices" chapter, and Recommended Turfgrass Cultivars for Certified Sod Production and Seed Mixtures in Maryland. 2016. University of Maryland.

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 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

Environmental issues concerning construction will have been 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 prevent environmental impacts to the site. For more information, see An Environmental Approach to Golf Course Development. 2008. American Society of Golf Course Architects.

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.

Grow-In

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. 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.

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. When using sod, nutrient applications should be delayed 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.

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 Chesapeake Bay and its tributaries. Therefore, erosion and sediment control are a critical component of construction and grow-in of a golf course. The MDE's 2011 Maryland Standards and Specifications for Soil Erosion and Sediment Control handbook provides detailed information on this topic and regulations.

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. Specific sediment-control requirements include the mapping of slopes steeper than 15%, of

highly erodible soils, and of vegetative buffer strips; submitting a narrative describing how erosion and sediment control will be integrated into the stormwater management strategy; and providing 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.

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.
- Hydro-seeding or hydro-mulching offer soil stabilization.

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.

Best Management Practices

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

Figure 1. Wetland area incorporated into the golf course design. Photo credit: Joseph Roberts.

Figure 2. Native vegetation serves as an effective riparian buffer for wetlands. Photo credit: Joseph Roberts.

Figure 3. Riparian buffer at Cedar Point Golf Course located at the confluence of the Patuxent River and Chesapeake Bay. Photo credit: David Burkhart.

Drainage

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

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, but 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.

Figure 4. Drainage installation during the construction of a new tee. Photo credit: Thomas Turner.

Habitat Considerations

Golf courses occupy large acreages, generally in urban areas, providing critical links between urban and rural/natural environments. In addition, golf courses can provide native areas and wildflower areas for native or managed species of pollinators in out-of-play area. Maintaining wildlife and pollinator habitat (as described in the "Pollinator Protection" chapter) on golf courses better protects biological diversity, which is especially important in the urban environment.

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 federal or state government, including species the state deems “of special concern.”
- Preserve critical habitat.

- Consult with the Maryland Department of Natural Resources' Wildlife and Heritage Service Natural Heritage Program 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.
- Retain riparian buffers along waterways to protect water quality and provide food, nesting sites, and cover for wildlife.

Figure 5. Golf courses provide habitat for different species, such as tree swallows (top left) and great blue herons (top right) and turtles. Photo credit: Jon Lobenstine.

Figure 6. Bluebird nest boxes at Falls Road Golf Course. Photo credit: Jon Lobenstine.

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. 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.

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.

Irrigation

The supplemental use of water for course play and non-play areas is essential to supporting healthy turfgrass and sustaining optimal course 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 that maximize plant health and reduce the potential for negative impacts on natural resources. Water quality protection is an integrated approach that includes irrigation practices, pesticide and nutrient practices, and regulatory compliance measures and structural measures as they concern environmental stewardship and policy.

Irrigation BMPs may also provide an economic, regulatory compliance, and environmental stewardship advantage to those who consider them part of 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, and limit repair and overall personal and public liability.

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 Maryland require a Water Appropriation Permit (WAP) from the MDE. Permitted users with withdrawals (surface water or groundwater) exceeding 10,000 gallons per day are required to report monthly withdrawals to MDE. MDE maintains a permit guide with information on water use appropriation and permits.

MDE maintains the state's official drought status. Maryland uses a four-stage approach to drought status. Superintendents should be aware when Stage 3 (Warning) and Stage 4 (Emergency) drought conditions are declared. At Stage 3, golf course compliance with water use restrictions is voluntary. At Stage 4, restrictions are mandatory for non-essential water uses, including prohibitions on irrigation and watering on golf courses, with the following exceptions:

- Watering of tees and greens between the hours of 8 p.m. and 8 a.m.
- Watering of localized areas with a handheld hose at the minimum rate necessary.
- Watering fairways when irrigation is reduced by at least 30%.
- As part of a necessary overseeding or resodding operation during September and October at the minimum rate necessary.

During a Stage 4 drought, sources of water other than potable water should be used when available. In addition, irrigation of rough areas is not allowed. For more information on water use restrictions during drought, see the Maryland Statewide Conservation Water Conservation Advisory Committee Final Report. 2000.

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.

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 turf to help cool the plants as it evaporates, may be beneficial under certain conditions. These conditions include turf with a very shallow root system, turf compromised by disease or 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 the in-play areas of the course, 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. 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. The Maryland Native Plant Society provides information on native plants in the state and the National Park Service offers information on native plants for Maryland. A list of drought-tolerant plants for landscape beds is available in Xeriscaping and Conserving Water in the Landscape. 2001. University of Maryland Extension.

Superintendents can plan ahead by developing a water conservation plan to achieve a 10% reduction in water use before mandatory water restrictions are enacted. Communication should be maintained with water managers, golf club members, and the public to explain your water conservation efforts as a proactive approach to addressing water-related issues.

Best Management Practices

- Selecting drought-tolerant varieties of turfgrass to minimize water use.
- Utilize hand watering or targeted irrigation to conserve water.
- Control invasive plants or plants that use excessive water.
- Reduce the amount of area on the golf course that is irrigated, if possible, such as non-play areas.
- Operate the irrigation system to provide only the water that is actually needed by the plants or to meet occasional special needs such as salt removal.
- Identify opportunities to achieve water use reductions before mandatory water restrictions are enacted in times of drought.
- During a drought, monitor the state's drought status to ensure compliance with restrictions.

Figure 8. Use of native grasses in the rough can help to reduce water use and augment the site's aesthetic appeal. Photo credit: Tom Turner.

Figure 7. Drainage project on #18 fairway at Cedar Point Golf Course. Water is carried back and empties into an irrigation pond providing up to 1 million gallons of recovered rainwater each year. Photo credit: David Burkhart.

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. In Maryland, Class IV reclaimed water is approved for use on golf courses. MDE publishes guidelines for the use of reclaimed water.

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, sodic water system treatment options should be included in the budget to address water quality and equipment maintenance.

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 device 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 the shallow groundwater table of fresh water 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

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, the local regulatory authorities should be contacted to determine the permitting and construction requirements and the required isolation distances from potential sources of contamination. 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, or fertilizer storage facilities.

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 MDE.
- Inspect wellheads and the well casing at least annually for leaks or cracks. 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.
- Never mix and load pesticide next to a wellhead if not on a pesticide mix/load pad.

Irrigation System Design

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.

Best Management Practices

- New and upgraded irrigation system designs should deliver water with maximum efficiency, focusing on precision water placement and distribution.
- Design and/or maintain a system to meet a site's peak water requirements under normal conditions with the flexibility to adapt to various water demands and local restrictions.
- Design should account for optimal distribution efficiency and effective root-zone moisture coverage. Target 80% or better Distribution Uniformity (DU).
- Design should allow the putting surface, slopes, and surrounds to be watered independently.
- The design package should include a general irrigation schedule with recommendations and instructions on modifying the schedule for local climatic, soil, and growing conditions. It should include the base evapotranspiration (ET) rate for the particular location.
- The application rate must not exceed the infiltration rate, which is the ability of the soil to absorb and retain the water applied during any one application. Conduct saturated hydraulic conductivity tests periodically.
- The design operating pressure must not be greater than the available source pressure.

- The design operating pressure must account for peak-use times and supply-line pressures at final buildout for the entire system.
- Turf and landscape areas should be zoned separately. Specific-use areas that should be zoned include greens, tees, primary roughs, secondary roughs, fairways, native areas, trees, and shrubs.
- Design should account for the need to leach out salt buildup from poor-quality water sources by providing access to fresh water.
- Only qualified specialists should install the irrigation system.
- Construction must be consistent with the design.
- The designer must approve any design changes before construction.
- Construction and materials must meet existing standards and criteria.
- Prior to construction, all underground cables, pipes, and other obstacles must be identified and their locations flagged.
- Permanent irrigation sprinklers and other distribution devices should be spaced according to the manufacturer's recommendations.
- Spacing should be based on average wind conditions during irrigation.
- Distribution devices and pipe sizes should be designed for optimal uniform coverage and flow rate.
- Distribution equipment, such as sprinklers, rotors, and micro-irrigation devices, in a given zone must have the same precipitation rate.
- Heads for turf areas should be spaced for head-to-head coverage.
- Water supply systems (for example, wells and pipelines) should be designed for varying control devices, rain shut-off devices, and backflow prevention.
- Water conveyance systems should be designed with thrust blocks and air-release valves.
- Flow velocity must be 5 feet per second or less.
- Pipelines should be designed to provide the system with the appropriate pressure required for maximum irrigation uniformity.
- Pressure-regulating or compensating equipment must be used where the system pressure exceeds the manufacturer’s recommendations.
- Equipment with check valves must be used in low areas to prevent low head drainage.
- Isolation valves should be installed in a manner that allows critical areas to remain functional.
- Manual quick-coupler valves should be installed near greens, tees, and bunkers and in fairways if possible, so that these areas can be hand-watered during severe droughts.
- Use part-circle or adjustable heads to avoid overspray of impervious areas, such as roadways and sidewalks, and surface waters such as lakes, ponds, and wetland margins.
- Update multi-row sprinklers with single head control to conserve water and to enhance efficiency.
- Incorporate multiple nozzle configurations to add flexibility and enhance efficiency and distribution.
- Ensure heads are set level to the ground.

Irrigation Pumping System Design

Pump stations should be efficient and sized to provide adequate flow and pressure. They should be equipped with control systems that protect distribution piping, provide for emergency shutdown necessitated by line breaks, and allow maximum system scheduling flexibility. Variable frequency drive (VFD) pumping systems should be considered if dramatically variable flow rates are required, if electrical transients (such spikes and surges) are infrequent, and if the superintendent has access to qualified technical support.

Best Management Practices

- The design operating pressure must account for peak-use times and supply-line pressures at final buildout for the entire system.
- Maintain the air-relief and vacuum-breaker valves by using hydraulic pressure-sustaining values.
- Install VFD systems to lengthen the life of older pipes and fittings until the golf course can afford a new irrigation system.
- An irrigation system should also have high- and low-pressure sensors that shut down the system in case of breaks and malfunctions.
- Pumps should be sized to provide adequate flow and pressure.
- Pumps should be equipped with control systems to protect distribution piping.

Figure 9. Pump station at Cattail Creek Country Club. Photo credit: Chris Harriman.

Figure 10. Pump station at Baltimore Country Club. Photo credit: Mark Jones.

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. Good system management starts with good preventive maintenance procedures and recordkeeping. 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. As maintenance costs increase, an evaluation of whether a system renovation is needed should be conducted.

Best Management Practices

Calibration and Auditing

- 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 the manufacturer's 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.

Preventive Maintenance

- Inspect the system daily for proper operation by checking computer logs and visually inspecting the pump station, remote controllers, and irrigation heads. A visual inspection should be carried out 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.
- Winterize the irrigation system to prevent damage.

Sprinkler Maintenance

Good system management starts with good preventive maintenance procedures and record keeping. This can be done during maintenance programs such as fertilizer or chemical applications where irrigation is required, or the heads can be brought on-line for a few seconds and observed for proper operation. However, maintaining a system is more than just fixing heads. It also includes documenting system- and maintenance-related details so potential problems can be addressed before expensive repairs are needed. Documentation also provides a basis for evaluating renovation or replacement options. Being proactive includes addressing larger issues if the system requires frequent repairs and determining the cause of failures. For example, pipe failures may be caused not only by material failure, but also by problems with the pump station; wiring problems may be caused by corrosion, rodent damage, or frequent lightning or power surges; and control tubing problems can result from poor filtration.

Best Management Practices

- Document equipment run-time hours.
- Document and periodically review the condition of infrastructure, such as pipes, wires, and fittings.
- Follow the manufacturer’s recommendations for system checks and routine maintenance.
- Routinely inspect the system for proper operation by checking computer logs and visually inspecting the pump station, remote controllers, and irrigation heads.

- A visual inspection should be carried out for leaks, misaligned or inoperable heads, and chronic wet or dry spots, so that adjustments can be made or parts replaced.
- 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.

Figure 11. Irrigation heads can be brought on-line for a few seconds and observed for proper operation. Photo credit: Mark Jones.

Irrigation Leak Detection

Irrigation systems are complex systems that 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.

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

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

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 return on financial and management benefits.

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 ensures that the system is functioning properly.

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 housing. 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

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

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 the manufacturer's 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.

Sensor Technology

Soil moisture sensors and other irrigation management tools should be installed in representative locations and maintained 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. The use of soil moisture probes, computer models, and tensiometers, as well as visual inspections for symptoms such as wilting turf, may 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 to daily access weather information and ET rates to determine site-specific water needs.

Best Management Practices

- Irrigation controllers/timers should be reset as often as practically possible to account for plant growth requirements and local climatic conditions.
- Properly calibrated flow meters, soil moisture sensors, rain shut-off devices, and/or other automated methods should be used to manage irrigation.
- Irrigation rates should not exceed the maximum ability of the soil to absorb and hold the water applied at any one time.
- Irrigation should not occur on a calendar-based schedule, but should be based on ET rates and soil moisture replacement.
- Computerized control systems should be installed on all new course irrigation systems to help ensure efficient irrigation application. These allow for timing adjustments at every head.

- Rain shut-off devices and rain gauges should be placed in open areas to prevent erroneous readings.
- Use multiple soil moisture sensors/meters for accuracy and to reflect soil moisture levels.

Figure 12. On-site weather stations access weather information and ET rates to determine site-specific water needs. Photo credit: Mark Jones.

Irrigation System Scheduling

Irrigation scheduling must take plant water requirements and soil intake capacity into account to prevent excessive water use that could contribute to leaching and runoff. Plant water needs are determined by ET rates, recent rainfall, recent temperature extremes, and soil moisture. ET rates and soil moisture replacement should determine the irrigation schedule. Because electric/mechanical clocks cannot automatically adjust for changing ET rates, frequent adjustment is necessary to compensate for the needs of individual turfgrass areas using these older systems. In low-maintenance areas, such as golf course roughs and, possibly, fairways, 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 roots are in the top several inches of soil. For fairways and roughs, use infrequent, deep irrigation to supply sufficient water for plants and to encourage deep rooting.

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.
- An irrigation system should be shut off after 0.25 to 0.5 inches of rain falls.
- Avoid use of a global setting; make adjustments to watering times per head.
- Permanent irrigation sprinklers and other distribution devices should be spaced according to the manufacturer's recommendations.
- Spacing should also be based 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.
- The computed daily ET rate can be used 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.
- Irrigation quantities should not exceed the available moisture storage in the root zone.
- The irrigation schedule should coincide with other management practices, such as the application of nutrients, herbicides, or other chemicals.
- Irrigation should occur 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.

Figure 13. Sensors such as the water sensor (left) and soil temperature sensor (right) can aid in irrigation decision making. Photo credit: Joseph Roberts.

Figure 14. Irrigation system monitoring. Photo credit: Mark Jones.

Metering

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

Best Management Practices

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

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 to both manage stormwater and function as a source for irrigation.

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 detain a two- or five-year rain event, reasonably draining the precipitation in a matter of hours, as excess water not absorbed by the soil flows through the drainage system, is temporarily held, and finally 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 detain more water for perhaps a longer period of time. This ability to detain large amounts of water requires accurate engineering and extensive construction to prevent physical or financial damage to the facility. Many BMPs are intended to prolong the detention process as long as practical, retain as much of the stormwater in surface or underground storage as reasonable, and to improve the quality of water leaving the property when possible.

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.

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

Figure 15. Many BMPs to manage stormwater prolong the water detention process as long as practical, as in this detention pond at Baltimore Country Club. Photo credit: Mark Jones.

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. MDE sets standards for the level of protection afforded to each body of surface water in the state (see COMAR 26.08.01 and COMAR 26.08.02). 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 and all its amendments. In practice, Maryland'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 MDE's Surface Water Quality Standards. Water quality information can be found in MDE's Water Quality Data.

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 that 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 Maryland's TMDLs, including information on nitrogen and phosphorus, can be found at the Maryland TMDL Data Center.

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, or restoration blueprints, that detail specific actions each would take to meet their pollution reduction goals by 2025. The blueprints guide local and state Bay restoration efforts through the next decade and beyond.

Maryland 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 the permanent impacts associated with development activities. New development projects must follow regulatory requirements that act to allow runoff to infiltrate through the soil and recharge groundwater supplies. MDE's Maryland Stormwater Design Manual is the official guide for stormwater management principles, methods, and practices in Maryland. Requirements to use environmental site design (ESD) to the maximum extent practicable to provide stormwater management went

into effect in May 2010. All jurisdictions in Maryland are implementing ESD for new development and redevelopment projects. For more information on ESD, see Chapter 5 "Environmental Site Design" in the Maryland Stormwater Design Manual.

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. Examples of structural BMP include 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. 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.

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.

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 planted.

Figure 16. Stream buffers act as natural biofilters that protect surface water quality, such as the vegetated buffers at Poolesville Golf Course. Photo credit: Jon Lobenstine.

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.

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

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.

Best Management Practices

- Maintain appropriate silt fencing and BMP 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 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 BMP 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
- 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, an important BMP is to maintain a riparian buffer around surfaces waters to filter the nutrients and sediments in runoff. By regulation, 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. Other management practices, such as establishing a special management zone around pond edges, can assist in efforts to prevent nutrient enrichment and sedimentation.

Best Management Practices

- Maintain a riparian buffer to filter the nutrients and sediment in runoff.
- Reduce the frequency of mowing at the lake edge. Collect clippings or direct them to upland areas.
- 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.
- Manipulate water levels to prevent low levels that result in warmer temperatures and lowered DO levels.
- Aerate ponds. Dredge or remove sediment before it becomes a problem.

Figure 17. Maintaining riparian buffers around waterbodies protects water quality. Photo credit: Chris Harriman.

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.

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.

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.
- Use artificial aeration (diffusers) if needed to maintain adequate DO.

Figure 18. Artificial aeration helps to maintain DO levels, like this solar powered sub-surface aeration system in use at the Army Navy Country Club. Photo credit: Sandra Burton.

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 Maryland, see Urban and Stormwater Pond Management and see Plants Recommended for Stormwater Ponds for Maryland-specific native aquatic plant recommendations.

Best Management Practices

- Ponds are more resistant to problems if they have a narrow fringe of vegetation along the edge, instead of highly maintained turfgrass.
- 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). The use of algaecides requires a permit from MDE and must be applied by a licensed applicator.
- To reduce the risk of oxygen depletion, use an algaecide containing hydrogen peroxide instead of one with copper or endothall.
- 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 from MDE.
- Do not use grass carp to control aquatic plants, as this fish is not legal in Maryland.

Water Quality Monitoring

Water quality monitoring can be used to determine whether outside events are changing the water quality entering the golf course, or whether the golf course is having a positive, neutral, or negative effect on water quality. It also provides a body of evidence of the golf course's environmental impact.

The number of samples per course is highly variable and depends on the size, location, and number of water sources on or near the golf course. The entry and exit points of golf course water sources are logical sampling points. However, sampling and analysis of standing water sources (ponds and lakes), springs, and any other irrigation sources should also be conducted. For golf courses in the planning stage, baseline water quality levels should be measured prior to construction at points of entry and exit of flowing water sources on or surrounding the golf course and on any surface water. This information can be used to form a baseline of flow and nutrient/chemical levels. For established courses, ongoing, routine water sampling provides meaningful trends over time. A single sample is rarely meaningful in isolation.

Figure 19. Collecting a water quality sample at Baltimore Country Club. Photo credit: Mark Jones.

Sampling parameters are based on golf course operation and basin-specific parameters of concern, such as TMDLs. Typically, samples should be analyzed for nutrients, pH and alkalinity, sediments, and suspended solids; additional analysis can include DO, heavy metals, and any pesticides used on the golf course. Samples should be analyzed by a certified laboratory and all quality assurance/quality control (QA/QC) procedures must be followed. Golf course

management must have good data to make good decisions. If a golf course should ever need to produce data for an agency or go to court to defend the facility, the data must meet QA/QC standards to be defensible as evidence.

For more information on developing a water quality monitoring program and for an example water quality monitoring report, see Appendix A in Environmental Best Management Practices for Virginia's Golf Courses. 2012. Virginia Golf Course Superintendent Association (VGCSA).

Best Management Practices

- Prior to construction, establish baseline water quality levels.
- A seasonal sampling program (four samples per year) is recommended. Semi-annual testing is acceptable once baseline data is established.
- Identify appropriate sampling locations and sample at the same locations.
- Follow recommended sample collection and analytical procedures.
- Implement corrective procedures if indicated in water quality monitoring reports.

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. Potential sources of leaching and runoff of N and P include fertilization of landscapes. However, properly fertilized and maintained turfgrass on golf courses has minimal impact on elevating N and P levels of ground or surface water. In addition, as discussed in the following section on regulations, state laws regarding fertilizer applications specify how N and P may be applied to turfgrass in Maryland, including golf courses.

Proper nutrient management plays a key role in the reduction of environmental risk and increases course profitability. Among other benefits, applied nutrients allow turfgrass to recover from damage, increase its resistance to stress, and boost its playability. The goal of a proper nutrient management plan should be to apply the minimum necessary nutrients to achieve an acceptable playing surface, to apply nutrients in a manner that maximizes their uptake, and to maintain turfgrass density and its associated environmental benefits.

Regulatory Considerations

Nutrient management regulations passed by the Maryland Legislature in 1998 require that the University of Maryland nutrient management guidelines be followed on state property and commercially managed turfgrass sites, including golf courses. In 2011, additional regulations further specified how N and P can be applied to turfgrass sites, as well as requiring state training and certification of nutrient applicators. These regulations became effective in 2013 and limit application of fertilizers as follows:

Maintenance N and P Fertilizer Applications

- Water soluble N fertilizers are limited to 0.7 pounds actual N per 1000 ft^2 per application.
- Slow release N fertilizers are limited to 0.9 pounds actual N per 1000 ft^2 per application.
- Fertilizers classified as an enhanced efficiency N fertilizer are allowed up to 2.5 pounds actual N per 1000 ft^2, as long as 80% of the annual rate for a given turfgrass species is not exceeded.
- Between December 1 and March 1, N fertilizers cannot be applied to golf course turf.
- Between November 15 and November 30, 0.5 pounds actual N per 1000 ft^2 can be applied, but only using a soluble N source.
- P applications must be based on soil test recommendations; however, P cannot be applied between December 1 and March 1.
- N or P fertilizer applications cannot be applied to impervious surfaces such as walkways, driveways, and roadways. Any fertilizer that lands on impervious surfaces must be removed or returned to the turf, such as by sweeping or blowing.
- Fertilizers containing N or P cannot be applied to frozen ground, regardless of the date
- No fertilizer containing N or P can be applied within 15 feet of specified waterways. If a drop spreader, rotary spreader with a deflector plate, or a targeted liquid spray is used for applications, then fertilizer can be applied no closer than 10 feet from such waterways.

Such waterways include surface waters subject to the jurisdiction of the state; the Chesapeake Bay and its tributaries; ponds, lakes, public ditches, or tax ditches within the state; and drainage systems within the state other than those designed and sued to collect, convey, or dispose of sanitary sewage.

Establishment N and P Fertilizer Applications

- Although highly recommended, a soil test for P applications to the seedbed or prior to laying of sod is not required if the following conditions are met:
  a) The application is made for the purpose of establishing turf on bare ground
  b) The application rate is made in accordance with the seeding recommendations of the University of Maryland (Table 1), and
  c) The land has been disturbed, such as by construction or tillage.
- A soil test is required for P application if an existing turfgrass area is being overseeded but the area is not being tilled. For example, overseeding existing tees or fairways using a slicer-seeder would require a soil test before P can be applied.
- No P can be applied between to a seedbed or an area to be sodded between November 15 and March 1.
- No N can be applied to a seedbed or an area to be sodded between December 1 and March 1. Between November 15 and November 30, 0.5 pounds actual N per 1000 ft^2 can be applied, but only using a soluble N source.
- Between March 1 and November 15 on areas to be seeded or sodded, a maximum application rate of 0.7 or 0.9 pounds actual N per 1000 ft^2 can be applied using a soluble or slow release N source, respectively.

Only a certified professional fertilizer applicator, or someone working under the direct supervision of a certified professional fertilizer applicator, can be paid to apply fertilizers. Professional Turfgrass Fertilizer Applicator Certificates are valid through June 30 of each year. Certificates may be renewed yearly for a $100 fee and verification of two hours of annual recertification training.

For more information, see:

- Maryland's fertilizer regulations
  http://mda.maryland.gov/resource_conservation/Documents/Fertilizer_Law.pdf
- Information related to training and certification
  http://mda.maryland.gov/resource_conservation/Pages/nutrient_management_training_program.aspx

Soil Testing

The purpose of a soil test is to provide a prediction of a plant's response to an applied nutrient. Through proper sampling, laboratory analysis, interpretation of results, application recommendations, and record keeping, soil testing can be used to manage nutrients more efficiently and in an environmentally sound method. A basic soil test will provide availability values for soil reaction (pH), P, potassium (K), calcium (Ca), and magnesium (Mg). Additional

tests can provide information on soil organic matter, soil micronutrients, and soluble salt levels, among other characteristics. Keeping soil test results from prior years will allow monitoring changes in soil nutrient levels over time and provide evidence of the impact of nutrient management plans. In Maryland, maintenance P applications must be based on soil test recommendations obtained at least every three years.

The University of Maryland Extension maintains a list of soil test laboratories and guidance on conducting soil tests (see Selecting and Using a Soil Test Laboratory. 2013. University of Maryland).

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.
- It is desirable to use the same soil testing laboratory for subsequent soil tests so that easy comparisons of changes in soil fertility values over time can be made.

Figure 20. Soil testing should be used to manage nutrients more efficiently and in an environmentally sound method. Photo credit: Joseph Roberts.

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 tests indicate the level of available essential nutrients in the soil, they do not indicate what the plant has actually taken up. Analysis of turfgrass tissue samples indicates the level of macro and micronutrients actually in the plant. However, low tissue levels of a given plant nutrient may not indicate a lack of nutrient availability but rather an abiotic problem, such as stress, or a biotic problem, such as a root pathogen, 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.

Fertilizers Used in Golf Course Management

Understanding the components of fertilizers, the fertilizer label, and the function of each element within the plant are all essential in the development of an efficient nutrient management program. Macronutrients are required in the greatest quantities and include N, P, and K. Learning about the role of each macronutrient within the plant provides a greater understanding of why these nutrients play such a key role in proper turfgrass management. Nutrient management guidelines are published by the University of Maryland (see Nutrient Management Guidelines for Golf Courses in Maryland. 2013. University of Maryland) and should be followed in order to ensure compliance with state regulations.

Nitrogen Sources

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.

The amount of N fertilizer that can be used in any single application is dependent on the type of N fertilizer, as defined by Maryland regulations.

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. As discussed in the Regulatory Considerations section of this chapter, the 2011 Maryland regulations on turfgrass fertilization limit the application of water soluble N fertilizers to 0.7 pounds actual N per 1,000 ft^2 per application.

Slow Release Nitrogen

Slow release N fertilizers contain N in a form that delays its availability for plant uptake after application. It extends 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. To

be considered a slow release N fertilizer, the fertilizer must contain at least 20% water insoluble or controlled release N. The N in all slow release fertilizers used for turfgrass maintenance, including natural organics, is ultimately converted in the soil to NH_4-N.

Slow release fertilizers are less prone to N leaching and runoff, compared with soluble fertilizers applied in excess of recommended rates. While varying considerably in individual characteristics and release patterns, slow release N fertilizers typically provide more even turfgrass response and provide N for turfgrass uptake over a longer period of time. The use of slow release fertilizers should particularly be considered on sites that are prone to leaching or runoff and when an N application needs to be made to turfgrass during non-optimum growing conditions.

The 2011 Maryland turfgrass fertilization regulations limit the application of slow release N fertilizers to 0.9 pounds actual N per 1,000 ft^2 per application.

Natural Organic Nitrogen

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.

Enhanced Efficiency Nitrogen

Enhanced efficiency N fertilizers are a type of slow release N fertilizers that further decrease the potential for nutrient loss to the environment and release less than 0.7 pounds N per 1,000 ft^2 per month. If a turfgrass fertilizer is classified as an enhanced efficiency N fertilizer, Maryland regulations allow up to 2.5 pounds of actual N per 1,000 ft^2 to be applied in one application, as long as 80% of the annual rate for a given turfgrass species is not exceeded.

Phosphorus and Potassium

Adequate soil P and K are essential for satisfactory turfgrass growth and performance. Phosphorus is particularly critical for new sites being established from seed, or for overseeding turf during renovation projects. Established turf, however, can generally tolerate relatively low levels of soil P. Natural organic fertilizers that contain P cannot be applied to turfgrass areas that have soil test P levels measuring optimum or excessive. On turfgrass that has low or medium soil P levels, natural organic fertilizers cannot be applied in excess of the amount of P recommended by the soil test, cannot be applied at a rate of more than 0.25 pounds of P_20_5 per 1,000 ft^2 per application, and cannot exceed 0.5 pounds of P_20_5 per 1,000 ft^2 annually.

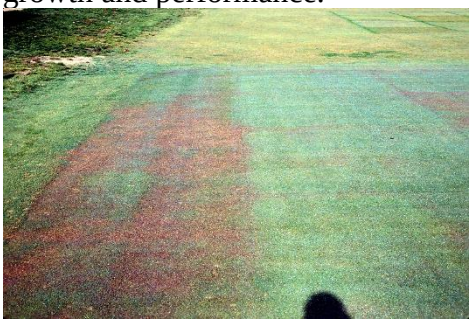


Figure 21. Phosphorus deficiency in putting green. Photo credit: Thomas Turner.

Potassium is generally more critical for established turf and may play a role in drought, heat, cold, and wear tolerance.

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 calcium (Ca), magnesium (Mg), and sulfur (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.

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 iron (Fe), manganese (Mn), boron (B), copper (Cu), zinc (Zn), molybdenum (Mo), and chlorine (Cl).

- *Iron*: Part of the catalytic enzymes, Fe is required for chlorophyll synthesis affecting photosynthesis, nitrogen fixation, and respiration.
- *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 also appears to be required for cell division in both leaves and shoots.

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 5.8 to 6.4 is generally considered ideal. Wide deviations from this range can result in reduced P and micronutrient availability and can interfere with soil N

metabolism and availability. Depending on turfgrass species, problems in turf may start to occur at soil pH above 7.8 and below 5.4. Thus, to maximize efficiency of nutrient availability and use, soil tests should be taken as recommended previously for soil P and K to determine soil pH.

Recommended limestone applications to achieve a soil pH of about 6.4 are available. (See Nutrient Management Guidelines for Commercial Turfgrass Seeding. 2005. University of Maryland.) If diseases such as take-all patch of bentgrass, summer patch of Kentucky bluegrass, or spring dead spot of bermudagrass are of concern, maintaining lower soil pH (5.4 to 5.7) may be desirable, and reduced or no limestone should be applied to achieve this level. Also, it is recommended, when practical, that limestone be applied approximately one month or more before seeding to minimize potential P availability problems and the potential for volatilization loss of applied N. 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.

Figure 22. Summer patch of Kentucky bluegrass cultivar differences in an NTEP trial. Photo credit: Thomas Turner.

Best Management Practices

- Test soil pH as part of soil testing.
- Adjust soil pH to recommended levels for a given turfgrass species and site.

Nutrient Management Planning

Environmental conditions vary greatly in Maryland and include differences among soils, topography, rainfall, and temperature. These differences require that a nutrient management plan be flexible enough to allow turfgrass managers to address their unique needs. In addition, a site analysis of the entire course should be conducted to identify those areas most prone to potential losses or potential impacts on water systems. These include highly sloped areas, areas immediately adjacent to water, and areas with sandy soils with high water tables. Understanding the timing for the most effective use of applied nutrients is important, as is knowing the different nutritional needs of various areas of the course. Examples of different needs include the following:

- Reduced height of cut and excessive traffic damage on putting greens result in an increased need for growth leading to an increase in nutrition needs.
- Tees and landing areas often have higher fertilization requirements than fairways and roughs because they suffer constant divot damage.
- Fairways and roughs often require lower nutrient inputs than other locations because of their increased height of cut, less damage, and clipping return.

Because the use of N and P fertilizers are regulated (see Maryland fertilizer regulations) and are of the greatest concern with respect to water quality, the application of these nutrients is discussed in greater detail below. Nutrient management guidelines are published by the

University of Maryland (see Nutrient Management Guidelines for Golf Courses in Maryland. 2013. University of Maryland).

Rates of N Application

The rates of nitrogen fertilizer application to golf course turf include restrictions on both:

- Rate of fertilizer applied per individual application.
- Total rate of fertilizer applied on an annual basis.

The rate per individual application is regulated on the basis of the nitrogen source (the percentage of soluble and slow release N contained in the fertilizer), as defined in the state's fertilizer regulations and discussed in the Fertilizers Used in Golf Course Management section of this chapter. The amount of N needed annually for satisfactory golf course turf depends on a number of factors, some of which can change from year to year. These include:

- turfgrass species
- age of turf
- length of growing season
- soil type and soil organic matter levels
- clipping removal
- irrigation intensity
- intensity of traffic and use of area
- prevalent weed and disease problems

Thus, total annual N application rates should be continually evaluated, both during a given season and on an annual basis. The ranges of annual N application rates typically needed for adequate growth and quality on Maryland golf courses are listed in the table below. These recommended ranges take into account the variability in the factors listed above.

For example, rates at the higher end of recommended ranges may be appropriate on sites where clippings are removed, irrigation intensity is high (which increases growth rates and nutrient uptake) and traffic is intense (such as heavily played public golf courses). In some situations, N rates somewhat higher than those listed in the table below are needed in an unusual year to meet the specific conditions and needs of a given golf course or site on a golf course. Rates at the lower end of the recommended ranges are often adequate on lightly or non-irrigated turf that receives less intense traffic, as well as on more mature turf. Some turfgrass species, such as fine fescue and zoysiagrass, inherently require less N to perform satisfactorily in Maryland and may deteriorate when more N is applied than is recommended. It is imperative that golf course superintendents evaluate annually the conditions and expectations at their own courses to determine appropriate rates.

Table 1. Recommended Annual N Rates for Maintenance of Golf Course Turf in Maryland
(as published in Nutrient Management Guidelines for Golf Courses in Maryland)

	Annual Rate* Pounds N/1,000 ft^2
GREENS	
Bentgrass	2.5 – 5.0
TEES	
Creeping bentgrass	2.0 – 4.0
Annual bluegrass	2.0 – 5.0
Kentucky bluegrass	3.0 – 5.0
Perennial ryegrass	2.0 – 4.0
Bermudagrass	2.0 – 4.0
Zoysiagrass	1.0 – 3.0
FAIRWAYS	
Creeping bentgrass	2.0 – 4.0
Kentucky bluegrass	2.5 – 4.0
Perennial ryegrass	2.0 – 4.0
Bermudagrass	2.0 – 4.0
Zoysiagrass	0 - 2.0
IRRIGATED ROUGHS**	
Creeping bentgrass	2.0 – 3.5
Kentucky bluegrass	2.5 – 3.5
Perennial ryegrass	2.0 – 3.5
Turf-type fall fescue	2.0 – 3.0
Bermudagrass	2.0 – 3.0
Zoysiagrass	0 – 2.0
NON-IRRIGATED ROUGHS	
Fine fescue	0 – 1.5
Kentucky bluegrass	2.5 – 3.0
Perennial ryegrass	2.0 – 3.0
Turf-type tall fescue	2.0 – 2.5
Bermudagrass	1.0 – 3.0

**Lower rates for maintenance may be adequate on soils with good organic matter levels, on turf older than five years, for selected cultivars of a given species, and/or on courses with lower than typical traffic. Rates up to 25% higher may be appropriate to maximize the establishment rate during the grow-in period of turf established from seed. Grow-in includes the period from the first mowing of turf (established from seed, sprigs, or plugs) to the date when turf is opened for play. Fertilization of turf established from sod should follow maintenance recommendations.*

***Irrigated roughs include areas adjacent to fairways that receive irrigation and may have clippings removed, but are maintained at a higher mowing height than fairways. Golf cart traffic may be intense on these areas.*

Timing of N Applications

The potential for N loss from turfgrass sites primarily occurs when an excessive rate of NO^3-N is applied to turf that is not actively growing. Thus, most of the annual fertilizer requirement should be applied during periods of active shoot (leaf blades, rhizomes, stolons) and/or root growth using NH_4-N based fertilizers.

The primary period for growth of warm season grass species (zoysiagrass, bermudagrass) is from mid-spring, after dormancy has broken, through mid-fall, when the first killing frost occurs. Thus, N applications should generally be restricted to this period. However, fertilizer that contains primarily NH_4-N can be applied up to a month before dormancy is typically broken in the spring, so that N is available for plant uptake when growth begins. This can be helpful in the recovery from winter damage and from spring dead spot of bermudagrass. Applications after September 1 are not generally recommended due to the possible enhancement of winterkill, particularly with bermudagrass. However, if bermudagrass has been overseeded with a cool season species such as perennial ryegrass, up to 0.9 pounds N per 1,000 ft^2 may be applied after September 1 to enhance its performance.

Cool season grasses generally have a longer growth period than warm season grasses in Maryland. They can exhibit growth at virtually anytime during the year if moisture and temperature conditions are conducive. The prime periods for growth on non-irrigated sites are typically from late winter through early summer, and from late summer through late fall.

Under extended hot and dry periods during mid-summer, cool season grasses may experience a period of dormancy until rainfall occurs. If irrigation is available or if rainfall is adequate throughout the summer, however, little dormancy will occur and N uptake will continue. Thus, periodic light applications of N (0.1 to 0.25 pounds N/1,000 ft^2) during the summer (when traffic can be intense due to high use of the golf course) can be especially beneficial to greens, tees, and fairways to maximize their recuperative capacity.

The 2011 Maryland turfgrass fertilization regulations further restrict the timing of application of N fertilizers on golf courses. Between December 1 and March 1, N fertilizers cannot be applied to golf course turf. Between November 15 and December 1, only 0.5 pounds N/1,000 ft^2 can be applied, and a soluble N source must be used.

P and K Applications

Phosphorus is particularly critical for new sites being established from seed, or for overseeding turf during renovation projects. Established turf, however, can generally tolerate relatively low levels of soil P. Potassium is generally more critical on established turf and may play a role in drought, heat, cold, and wear tolerance. Whereas K applications are not regulated, P applications must be based on soil test recommendations. However, there is one exception to the requirement for a soil test prior to the application of P. A soil test is not required if the application is made for the purpose of establishing turf on bare ground, the fertilizer is incorporated, and the application is made in accordance with seeding recommendations. (See Nutrient Management Guidelines for

Commercial Turfgrass Seeding. 2005. University of Maryland.) This exception does not pertain to overseeding existing turf.

Areas on the golf course that potentially will be fertilized should be sampled every three years. Putting greens and some tees present a unique situation. Due to the very high sand content of most greens and tees, the cation exchange capacity of these soils tends to be exceptionally low and, consequently, the storage capacity for most nutrients is very low. In addition, frequent irrigation (which increases growth rates) and clipping removal result in a fairly rapid depletion of existing nutrients. Thus, soil tests of high sand content greens and tees should preferably be done on an annual or biannual basis to monitor changes in soil P, K, and pH. 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 P and K applications based on soil tests are shown in Table 2 and Table 3 below.

Table 2. Phosphorus Application Recommendations for Golf Course Turf[+]
(as published in Nutrient Management Guidelines for Golf Courses in Maryland)

	Soil Test Phosphorus Category			
	Low	**Medium**	**High**	**Excessive**
	(in pounds P_2O_5 per 1,000 ft^2)			
Establishment				
Broadcast*	2 – 3	1 – 2	0 – 1	0
Incorporated**	3 – 4	1 – 2	0 – 1	0
Maintenance	2 – 3[++]	1 – 2	0	0

*+ Any subsequent applications should be based on additional soil tests. * Or incorporated into soil up to 2 inches. ** Incorporated into soil over a 2-inch depth. [++] 3 pounds P_2O_5/1,000 ft^2 should only be used on soil testing "very low" for P.*

Table 3. Potassium Application Recommendations for Golf Course Turf
(as published in Nutrient Management Guidelines for Golf Courses in Maryland)

	Soil Test Potassium Category			
	Low	**Medium**	**High**	**Excessive**
	(in pounds K_2O per 1,000 ft^2)			
Establishment				
Broadcast*	2 – 3	1 – 2	0 – 2	0
Incorporated**	3 – 5	1 – 2	0 – 2	0
Maintenance	2 – 4	1 – 3	0 – 2	0

** Or incorporated into soil up to 2 inches.*
*** Incorporated into soil over a 2-inch depth.*

Best Management Practices

- Follow Maryland fertilizer regulations and use in Nutrient Management Guidelines for Golf Courses in Maryland. 2013. University of Maryland.

- 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 ft2 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 and apply at a maximum rate of 0.9 pounds N per 1,000 ft2.
- 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.

Fertilizer Applications

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. 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.

Best Management Practices

- Calibrate equipment regularly.
- Use the appropriate type of applicator or spreader for the fertilizer.

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. Heavily used areas such as putting greens often deteriorate because of compacted soil, thatch accumulation, and excessive use. Soil problems from active use are usually limited to the top 3 inches of the soil profile and should be actively managed to enhance turf health and improve nutrient and water uptake.

Mowing

Mowing is the most basic yet most 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 will result in weakened turf with poor density and quality. Proper mowing height is a function of the cultivar being managed and of 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 allow 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.

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, 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 4 and 5 below:

Table 4. 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
Zoysiagrass	-	-	0.400	0.500
Perennial ryegrass	-	-	0.375	0.375
Kentucky bluegrass	-	-	0.500	0.625

Table 5. 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 - 2.5

** 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 tolerance, 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 completion, 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.

Best Management Practices

- Tall grass should be mowed frequently and height 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

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 6 (republished with permission from Environmental Best Management Practices for Virginia's Golf Courses, Table 7-3, p. 93):

Table 6. 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, or moisture or by 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.

Best Management Practices

- Mowing frequency should increase during periods of rapid growth and decrease during dry, stressful periods.
- Reduce mowing frequency under stressful conditions (heat, heavy traffic, drought, etc.) whenever possible.

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.

Best Management Practices

- Vary mowing patterns.
- On greens, change mowing direction every time.
- Reduce clean-up passes at times of stress.

Figure 23. Mowing directions should be altered whenever possible to prevent excessive lateral growth and maintain HOC. Photo credit: Chris Harriman.

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 development.

Best Management Practices

- 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 rotary mowers sharp and properly adjusted.

Figure 24. Reel mowers should be used whenever possible for maintaining low HOC. Photo credit: Joseph Roberts.

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 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. Plant growth regulators (PGRs) can also be used to reduce clipping production.

Best Management Practices

- Return clippings to canopy whenever possible to recycle nutrients and reduce the need for fertilizer inputs.
- Remove 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.

Figure 25. When clippings are not returned, they should be collected and disposed of properly, such as by composting or dispersing clippings evenly in natural areas. Photo credit: Joseph Roberts.

Cultivation

Cultivation involves disturbing the soil or thatch using various methods to achieve important agronomic goals: compaction relief, 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. Cultivation techniques include core aeration, deep drilling, verticutting, grooming, solid tining, and spiking/slicing. Table 7 lists these cultivation approaches and presents a relative ranking of the agronomic benefits of each (republished with permission from Environmental Best Management Practices for Virginia's Golf Courses, Table 7-4, p. 94):

Table 7. Turfgrass Cultivation 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
Verticutting	Low	Best	Medium	Low to high
Grooming	None	Very low	Very low	None
Solid tining	Low	None	High	Medium-low
Spiking/slicing	None	Very low	Low	None

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.

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.

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 verticutting (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 verticutting, shallow verticutting (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 verticutting can be practiced regularly during the growing season except in times of drought or excessive heat.

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/no compaction or thatch relief.

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.

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.
- Core aeration should take into account when weeds are germinated 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.
- Vary the depth of aeration events by incorporating different lengths of tines. This prevents the development of compacted layers in the soil profile.
- Verticutting depth for thatch removal should reach the bottom of the thatch layer and extend into the surface of the soil beneath the thatch.
- Solid tines cause less disturbance to the turf surface and can be used to temporarily reduce compaction and to soften surface hardness during months when the growth rate of grasses is reduced. Benefits of solid-tine aeration are temporary because no soil is removed from the profile.
- Solid tine aeration should be avoided on wet native soils because it causes compaction and reduction in water movement.
- Venting should be periodically performed to help provide oxygen to root zones, particularly prior to the onset of summer stress, and can also help dry out excessively wet soils.

Figure 26. Aeration manages soil compaction and aids in improvement of soil drainage by removing small cores or plugs from the soil profile. Photo credit: Chris Harriman.

Figure 27. Vertical mowing (verticutting) can be incorporated into a cultural management program to achieve a number of goals. Photo credit: Chris Harriman.

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 rates 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.

Best Management Practices

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

Figure 28. Topdressing the playing surface with sand improves surface firmness and smoothness, dilutes thatch, improves recovery from turf thinning or cultural practices, and, over time, modifies the root zone. Photo credit: Chris Harriman.

Rolling

Rolling of turf is performed at various intervals primarily to help smooth putting surfaces and increase green speed for daily play or tournaments. 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. In some instances, "target" rolling of greens will significantly reduce fuel emissions and labor while still providing an ideal putting surface near the hole where it is most beneficial to the golfer. 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.

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 greens.

Figure 29. Rolling of turf smooths putting surfaces and increases green speed for daily play or tournaments and should also be considered on fairways or tees to reduce the occurrence of some turf diseases. Photo credit: Chris Harriman.

Cultivar Selection

Maryland is located in a transition zone. Both cool season and warm season turfgrass can be grown, but the climate is not favorable for the growth of either group of grass over the entire year. To establish and maintain turfgrass, site preparation, the choice of cultivar, and correct management practices are essential. In western Maryland, or the mountain region, cool season grasses are better adapted. The coastal plain, southern Maryland and the eastern shore, as well as the piedmont region and central and northern Maryland, have warmer winters. Both cool season and warm season grass can be grown there. Tall fescue grows throughout Maryland.

Numerous new turfgrass cultivars continue to be developed and released by turfgrass breeders. However, while many of these cultivars are adapted to the environmental conditions that prevail in other regions of the country, many 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 Maryland and Virginia Tech. The cultivar performance data obtained at various trial locations are reviewed annually in a joint meeting of university researchers and representatives of the Department of Agriculture of both 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. Maryland test results and recommendations can be found on the NTEP website. Recommendations for Maryland are also published and updated annually in Recommended Turfgrass Cultivars for Certified Sod Production and Seed Mixtures in Maryland. 2016. University of Maryland. When selecting cultivars for a specific site, considerations include the desired use, site and microclimate conditions, disease resistance, and spring transition traits.

The Maryland Department of Agriculture administers the Maryland Certified Sod program. Certified sod must contain only the recommended cultivars. Requiring certified sod in specifications guarantees that the sod contains currently recommended cultivars, has been seeded in recommended percentages, and is of high quality with minimal pest problems.

Best Management Practices

- Follow grow-in BMPs as provided in the "Planning, Design, and Construction" chapter.
- Use only Maryland-certified sod.
- 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.

Figure 30. Gray leaf spot incidence difference in fairway perennial ryegrass in NTEP trial. Photo credit: Thomas Turner.

Figure 31. Field day at University of Maryland showing NTEP trial plots. Photo credit: Chris Harriman.

Overseeding Warm-Season Turfgrass

The fundamental purpose of overseeding is to establish a temporary cool-season grass into the warm-season base for improved color and playability during the fall and winter when the warm-season grass enters dormancy. Overseeding increases the need for irrigation and routine mowing and may result in significant thinning of the base grass during spring transition. Successful overseeding programs require year-long planning and incorporate all aspects of root-zone cultivation and weed control in an effort to maintain health of the warm-season turfgrass while allowing successful establishment of the overseeded cool-season grass species.

Best Management Practices

- Remove thatch to improve seed-to-soil contact as part of an active cultivation program before overseeding.
- Reduce or eliminate fertilization of the base grass three to four weeks before the planned seeding date to minimize growth and competition.
- Core-aerate the soil four to six weeks before the planned overseeding date to open turf canopy and aid in uniform establishment of overseeded grass.
- Select cultivars that are adapted to the desired use, taking note of disease resistance and spring transition traits.
- Irrigate newly planted overseed to maintain constant moisture levels, not allowing the soil surface to dry out. Gradually reduce irrigation once the seedlings have been mowed.
- Do not fertilize with nitrogen immediately before or during establishment of overseed as the N may encourage warm-season turfgrass competition and increase disease potential.
- Reduce fertilizer rates in the spring to slow the growth of overseeded grass. Once warm-season turfgrass regrowth is apparent, restore fertilizer applications to stimulate growth of the warm-season turfgrass.

Integrated Pest Management

In Maryland, integrated pest management (IPM) is described as follows[2]:

> *"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.

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, as discussed in the "Pesticide Management" and "Maintenance Operations" chapters.

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.

[2] From *Maryland Pesticide Applicator Core Manual*.

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 the environment and to minimize the development of pesticide resistance.

For more information related to selecting appropriate turfgrass cultivars for Maryland and implementing an IPM for turf in Maryland, 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.
- Maryland Pesticide Applicator Core Manual. National Association of State Departments of Agriculture Research Foundation.

Best Management Practices

- Develop a written IPM plan for your golf course. (Available resources for writing an IPM plan include the GCSAA's IPM information and Greengolfusa.com.)
- Select turfgrass cultivars recommended for use in Maryland 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.
- When chemical control is necessary, follow University of Maryland 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.

Identifying Pests

A number of key pests can impact turfgrass in Maryland. Being able to identify these key pests and understanding the 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 techniques. As a rule, healthy, well-managed turf better withstands pest outbreaks and recovers more rapidly than unhealthy turf. See Diagnosing Common Lawn and Athletic Field Diseases (2003, University of Maryland) as a reference to turf diseases in Maryland.

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 site-specific pest control measures rather than blanket applications of pesticides.

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.

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.

Figure 32. Scouting, such as for white grubs in the soil, is an important IPM method. Photo credit: Chris Harriman.

Pest Thresholds

IPM is commonly used in agricultural crop production, where the economic thresholds for key pests have been determined. Pest levels exceeding the site's threshold 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.

Best Management Practices

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

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.

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 on a golf course, turfgrass managers have multiple tactics and tools that can reduce the likelihood of disease. The most common cultural abuses that aggravate turf diseases include close and frequent mowing, poor drainage, excessive thatch, light and frequent irrigation, inadequate or excessive nitrogen fertilization, shade, and traffic. An example is summer patch, which is particularly damaging when turf is mowed too closely, given light and frequent irrigations, and fertilized with excessive amounts of nitrogen. The use of BMPs for cultural practices promotes healthy, well-managed turfgrass that is less likely to develop disease problems. Disease outbreaks that do occur are less likely to be severe on healthy turf because it has better recuperative potential than stressed, unhealthy turf.

For more information on the following turf diseases prevalent in Maryland and control methods, see:

- 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.

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. (For example, 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.

Figure 33. Red thread disease. Photo credit: Thomas Turner.

Figure 34. Brown patch mycelium. Photo credit: Thomas Turner.

Figure 35. Dollar spot. Photo credit: Joseph Roberts.

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 Maryland. Weeds such as these compete with desired plants for space, water, light, and nutrients and can harbor insects and diseases. They can be hosts for other pests such as plant pathogens, nematodes, and insects. Certain weeds can also cause allergic reactions in humans. 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 Maryland, including herbicide recommendations, see:

- 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.

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 broadleaf weeds.

Figure 36. Annual bluegrass encroachment in green. Photo credit: Thomas Turner.

Turf Insects/Arthropods

Many arthropods (especially insects and mites) occur 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 Maryland golf courses

include species such as annual white grubs, armyworms, cutworms, and nuisance ants.

Best Management Practices

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

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 30-80 larvae per square foot, which decreases as turf is 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, and vacuuming adults.

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. . In Maryland, 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 helps mask symptoms of ABW damage.

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

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.

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.

Best Management Practices

- When nematode activity is suspected, an assay of soil and turfgrass roots is recommended to determine the extent of the problem.
- Divert traffic away from areas that are stressed by insects, nematodes, diseases, or weeds.
- 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

The biological component of IPM involves the release and/or conservation of natural predators, such as parasites and pathogens, and other beneficial organisms. A few 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 organisms.

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 honeydew source.
- Avoid applying pesticides to roughs, driving ranges, or other low-use areas to provide a refuge for beneficial organisms.

Conventional Pesticides

IPM does not preclude the use of pesticides. However, pesticides should be viewed as just one of the many tools used to minimize pest problems. A pest-control strategy using pesticides should be used only 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, personnel 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. 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 label, as required by state and federal law.

Best Management Practices

- Train employees in proper pest identification and pesticide selection techniques.
- Choose the product most appropriate for the problem or pest.
- Mix only the quantity of pesticide needed in order to avoid disposal problems, protect non-target organisms, and save money.
- Spot-treat pests whenever appropriate.
- Make note of any environmental hazards and groundwater advisories included on the label.
- Rotate pesticide 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

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 Maryland regulations, but for IPM purposes should include additional information, such as monitoring records, weather records, cultural management logs, and pest response.

Best Management Practices

- Determine whether the corrective actions reduced or prevented pest populations, were economical, and minimized risks. Record and use this information when 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.

Pesticide Management

Pesticide use should be part of an overall pest management 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, its selection should be based on effectiveness, toxicity to non-target species, cost, site characteristics, and its solubility and persistence in 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 facilities for storing and handling pesticides be properly sited, designed, constructed, and operated in accordance with federal and Maryland regulations.

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 Maryland Department of Agriculture (MDA) Pesticide Regulation Section is designated as the lead agency for enforcement of the Maryland Pesticide Applicators Law (COMAR 15.05.01). As such, MDA 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 Maryland must be registered with the MDA's State Chemist Section. The Maryland Pesticide Registration and Labeling Law requires a distributor of a pesticide product to register every pesticide product each year with the State Chemist Section before that product can be sold or distributed in the state. The Maryland Pesticide Database is a searchable database of all registered pesticides.

In Maryland, pesticide storage areas must meet the following minimum requirements (COMAR15.05.01):

- 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 MDA 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 MDA.

Detailed descriptions of general regulatory requirements, as well as requirements for storage, transportation, licensing, and record keeping, are provided in:

- Maryland Pesticide Applicator Core Manual. National Association of State Departments of Agriculture Research Foundation.
- Pesticide Information Leaflet No. 35: Synopsis of the Maryland Pesticide Applicators Law and Regulations. 2012. University of Maryland Extension.

Human Health Risks

Pesticides belong to numerous chemical classes that vary greatly in their toxicity. The human health risk associated with pesticide use is related to both pesticide toxicity and level of exposure. Exposure to pesticides requires immediate attention, although 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) 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.
- Chapter 3 "Pesticide Labeling" of the Maryland Pesticide Applicator Core Manual.
- Chapter 5 "Pesticide Hazards and First Aid" of the Maryland Pesticide Applicator Core Manual.

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 for more information.

Personal Protective Equipment

Exposure to pesticides can be mitigated by practicing good work habits and adopting modern 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 exposure through one or more pathways: skin, eyes, oral ingestion, or respiratory tract. Pesticide labels list legal requirements for minimum PPE. 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 Chapter 6 "Personal Protective Equipment" of the Maryland Pesticide Applicator Core Manual.

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 is appropriate for the chemicals used as 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.
- Provide laundering facilities or uniform service for employee uniforms.
- The federal Occupational Safety and Health Administration (OSHA) requires employers to fit test workers who must wear tight-fitting respirators.
- Meet requirements for OSHA 1910.134 Respiratory Protection Program.

Environmental Fate and Transport

Environmental characteristics of a pesticide can often be determined by the environmental hazards statement found on pesticide product labels. 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.

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, in addition to the selection of the appropriate pesticide. Site-specific characteristics, such as soil type, 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 of Maryland's eastern shore allow water and dissolved compounds to freely percolate down to groundwater. In western Maryland, karsts (limestone formations with sinks or separations in the rock) underlie the soil. These sinks can act as direct entryways to groundwater for dissolved pesticides.

In addition to site characteristics, prevailing weather conditions, such as chance of precipitation, prevailing wind, 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.

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.

Weakly sorbed pesticides (compounds with small Koc values) are more likely to leach through the soil and reach groundwater. Conversely, strongly sorbed pesticides (compounds with large Koc values) are 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.

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 and the equipment used greatly influence the amount of drift that may occur. The pesticide label should be reviewed for specific information on drift reduction techniques or requirements. The applicator must also check weather conditions such as air stability, temperature, and wind direction and speed at the time and place of the application and follow all weather-related restrictions on the label.

Environmental fate- and transport-related topics are covered in 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.

Best Management Practices

- Use drift retardants when needed to 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.

Application Equipment and Calibration

Application equipment must apply the pesticide to 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. 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.

To apply pesticides at the proper rate, properly calibrated application equipment is essential. Such equipment mitigates environmental and human health concerns, reduces the chances of over- or under-applying pesticides, and optimizes pesticide efficacy. Equipment should also be checked frequently for leaks and malfunctions.

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

Best Management Practices

- Use an appropriately sized applicator for the size of area being treated.
- Ensure the spray technician is experienced, certified, and properly trained.
- Minimize off-target movement by using properly configured application equipment.
- 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 should be conducted for each person making the application to take into consideration their walking speed, etc.

Figure 37. Pesticide equipment should be properly calibrated and configured. Photo credit: Chris Harriman.

Pesticide Record Keeping

Maintaining accurate records of pesticide-related activities (for example, purchasing, storage, inventory, applications, etc.) is essential. Maryland requires that pesticide application records be maintained for a period of two years and made available to the Maryland Department of Agriculture upon request. The following information must be documented, when applicable:

- name of applicator or consultant
- date of application, recommendation, or pest identification
- pest and type of plant
- acreage or area treated
- address of treated property
- name of property
- common name and EPA registration number of pesticides used or recommended
- rate of concentration of pesticide used or recommended
- total amount of pesticide used
- EPA registration number of the product
- type of equipment used*
- time of day of application*
- wind direction and estimated velocity
- weather conditions at the site when the pesticide was applied* (This information is not required if the application consists of baits in bait stations or if it is indoors or within 3 feet of a structure.)

** Items marked with an asterisk are required to be recorded by commercial applicators, pest control consultants, and public agencies, but are not required for private applicators.*

Best Management Practices

- Keep and maintain records of all pesticides used in order to meet legal (federal, state, and local) reporting requirements.
- 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 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, Maryland 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 and handling in Maryland see the following:

- Pesticide Information Leaflet No. 39: Pesticide Storage and Security. 2012. University of Maryland.
- Chapter 8 "Transportation, Storage, and Security." Maryland Pesticide Applicator Core Manual. pp. 124-135.
- Pesticide Information Leaflet No. 35: Synopsis of the Maryland Pesticide Applicators Law and Regulations. 2012. University of Maryland.

Best Management Practices

- Maintain an inventory of all pesticides used 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.
- 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.
- 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, and on the spray rig.

Figure 38. Pesticide storage areas should be separate from storage areas for other chemicals. Photo credit: Joseph Roberts.

Mixing/Washing Station

Pesticide leaks or spills, if contained, will not percolate down through the soil into groundwater or run off the surface to contaminate streams, ditches, ponds, and other waterbodies. One of the best containment methods is the use of a properly designed and constructed chemical mixing center (CMC).

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 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 intended.

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.

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) or stored for use for the next compatible application.

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 in Maryland, 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. The MDA offers a pesticide container recycling program (see MDA's 2017 program brochure). Ways to reduce the amount of waste requiring handling include identifying and implementing waste-reduction practices and purchasing in bulk packaging when possible.

Best Management Practices

- 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.
- Rinse emptied pesticide containers by either triple rinsing or pressure rinsing.
- Puncture empty and rinsed pesticide containers and dispose of according to the label.

Emergency Preparedness and Spill Response

As required by Maryland's state regulation for the storage of pesticides, 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).

In Maryland, the MDA Pesticide Regulation section investigates accidents/incidents related to pesticides and agricultural fertilizers and must be notified immediately of any accident or spill involving a pesticide (410-841-5710). MDE Emergency Response Division offers a hotline (866-633-4686) for reporting and receiving assistance with immediate environmental emergencies and hazardous material spills that endanger the public. MDE must be notified of releases of materials

threatening or impacting surface and sub-surface public drinking water supplies and spill materials threatening or impacting groundwater, surface water, or any waters of the state. 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 in Maryland 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.

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 numbers for MDA, MDE, and CHEMTREC (800-424-9300), 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.
- 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.

Pollinators

Most flowering plants need pollination to reproduce and grow fruit. While some plants are pollinated by wind, many require assistance from insects, such as bees and butterflies, and animals, such as hummingbirds. In the absence of pollinators, many plant species, including the fruits and vegetables we eat, would fail to survive. Therefore, protecting bees and other pollinators is important to the sustainability of agriculture. The University of Maryland Extension provides information on the basics of pollinators.

Because pesticides are designed to control pests, their use can potentially impact non-target species. Therefore, pesticide applicators, including those on golf courses, need to be mindful of the impact that pesticides have on pollinator species and their habitat.

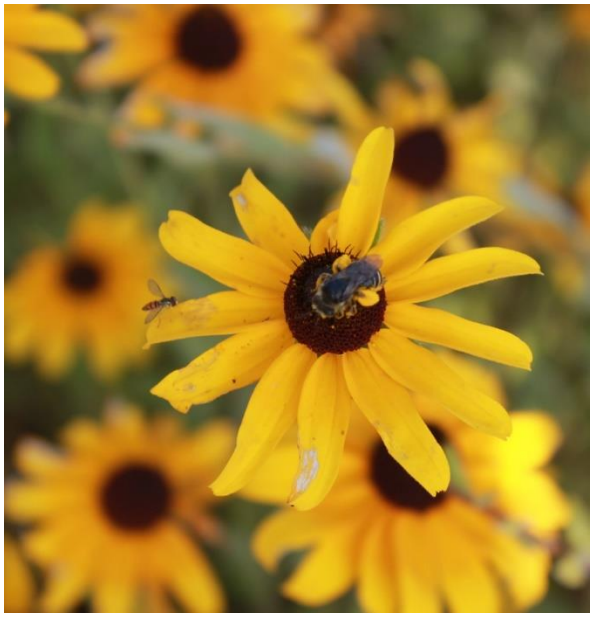


Figure 39. Golf courses can provide habitat for native and domestic species of pollinators.

Regulatory Considerations

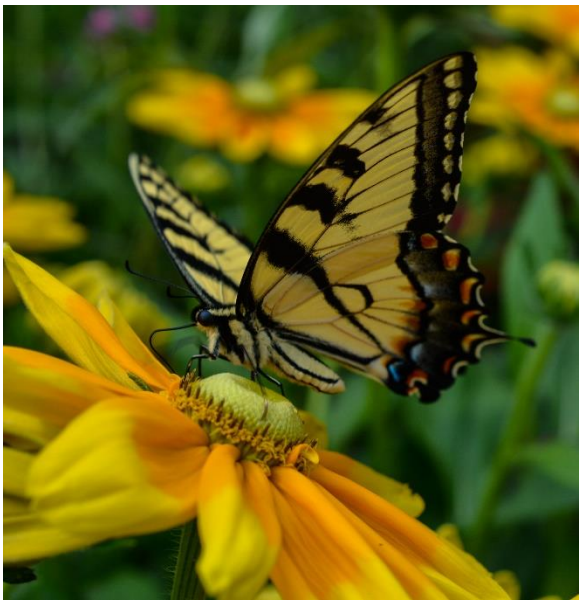
In 2016, Maryland became the first state to pass legislation through its General Assembly that restricts consumers from using neonicotinoids, which will go into effect in 2018. Under the Pollinator Protection Act, consumers will not be able to buy pesticides that contain neonicotinoids. Certified pesticide applicators, farmers and veterinarians will be still be allowed to use neonicotinoids. However, under the law, certified pesticide applicators on golf courses must follow pollinator-protection language on pesticide labels. Therefore, certified pesticide applicators must be aware of honey bee toxicity groups and able to understand precautionary statements. IPM principles recommend keeping records of all pest control activity for reference on past infestations or other problems to select the best course of action in the future.

Pest Management Practices to Protect Pollinators

It is important to minimize the impacts of pesticides on bees and other pollinators, as well as beneficial arthropods. Pesticide applicators must use appropriate tools to help manage pests while safeguarding pollinators, the environment, and humans. Using IPM to reduce pesticide usage and minimizing the potential of exposure when pesticides are needed are two important practices for protecting pollinators.

Best Management Practices

- Before applying a pesticide, scout/inspect the area for both harmful and beneficial insect populations, and use pesticides only when a threshold of damage has been indicated.
- Consider lures, baits, and pheromones as alternatives to insecticides for pest management.
- When pesticides are needed, select one – when possible -- with a lower impact on pollinators, such as granular formulations of pesticides that are known to be less hazardous to bees.
- Avoid applying pesticides during bloom season and mow first to remove blooms, including the blooms of flowering weeds.
- Avoid applications during unusually low temperatures or when dew is forecast.
- Do not apply pesticides when pollinators are active.
- Use the latest spray technologies, such as drift-reduction nozzles to prevent off-site translocation of pesticide.



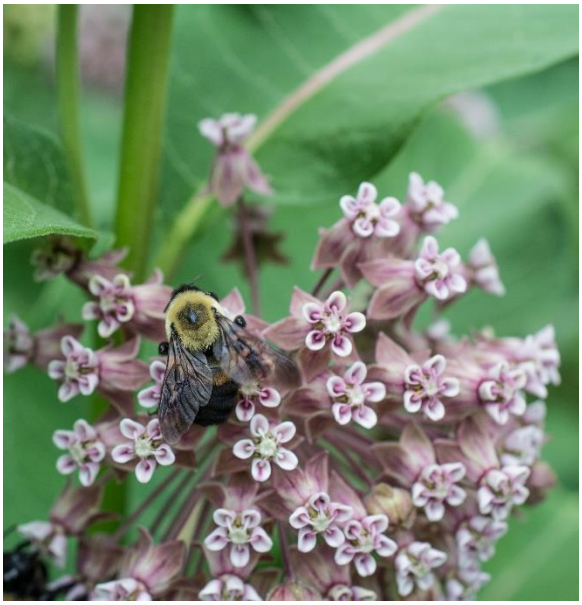


Figure 40. Pollinators at Baltimore Country Club. Photo credits: Mark Jones.

Enhancing Habitat for Pollinators

Habitat for pollinators includes foraging habitat and nesting sites. Enhancing pollinator habitat in non-play areas with a diversity of wildflower species provides a food source. General considerations for pollinator-friendly plantings include the following:

- plants with a variety of colors
- flowers with different shapes and sizes
- plants with different flowering times to provide forage all season
- plants with different heights and growth habits

Simple steps for providing nesting sites for native species can include leaving stems, coarse woody debris, and exposed patches of sand or well-drained soil in out-of-play areas. In addition, easy-to-construct nesting boxes or hollow bamboo sticks can be provided for solitary nesting species.

More information on planting for pollinator species in Maryland and beneficial plants can be found in the University of Maryland Extension's Plants that Attract Pollinators and Natural Enemies. 2015. University of Maryland. Making Room for Native Pollinators is a USGA publication that provides detailed information on creating foraging habitat, bee nesting habitat and man-made nest sites specifically on golf courses, as well as the basics of pollinator biology useful for pesticide applicators.

Best Management Practices

- When renovating out-of-play areas, plant a diversity of flowering pollinator-friendly plants.
- Leave nesting materials and sites in out-of-play areas when possible.
- Consider providing man-made nesting sites for solitary nesting species.

Maintenance Operations

One of the key principles of pollution prevention is to reduce the unnecessary use of potential pollutants. Over time, the routine discharge of even small amounts of solvents can result in serious environmental and liability consequences because of the accumulation of contaminants in soil or groundwater. Pollution prevention includes the proper storage, handling, and disposal of chemicals, washwater, and wastewater. For example, an equipment-washing facility can be a source of both surface water and groundwater pollution if the washwater generated is not properly handled. In particular, washwater from pesticide application equipment must be managed properly, since it contains pesticide residues. If not contaminated, wastewater can be reused or discharged to a permitted stormwater treatment system.

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.

Regulatory Considerations

Local regulations may be in place in your location. Early engagement among developers, designers, local community groups, and permitting agencies is essential to designing and constructing a golf maintenance and storage facility that minimizes environmental impact and meets the needs of the approval process. Additionally, local governments may regulate and dictate the required code and methods for backflow prevention.

At a minimum, Maryland regulations (COMAR 15.05.01) require that pesticide storage areas must meet requirements that include the following:

- 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 MDA 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 MDA.

In Maryland, all underground fuel storage tanks and 10,000 gallon or larger above-ground storage tanks are regulated by MDE. Local laws and regulations related to the storage of fuel

may vary. Maryland's regulations establish a much lower limit on the maximum amount of waste than federal regulations for qualifying as a "small quantity generator" of hazardous waste. In Maryland, as little as 100 kilograms of used solvents for disposal trigger state reporting requirements. Pesticides that have been mixed so they cannot be legally applied to a site in accordance with the label must be disposed of as a waste. Depending on the materials involved, they may be classified as hazardous waste.

In the event of a spill, contact the MDE Emergency Response Division (866-633-4686) and the National Response Center (800-424-8802) to determine if the amount constitutes a reportable quantity.

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 of this document.

Best Management Practices

- Storage buildings should have appropriate warning signs and placards.
- Develop an emergency response plan and educate all golf course personnel regarding emergency procedures on a regular basis.
- Individuals conducting emergency chemical cleanups should be properly trained under requirements of federal Occupational Safety and Health Administration (OSHA).
- Locate pesticide storage away from other buildings, especially fertilizer storage facilities.
- Floors of chemical storage buildings should be impervious and sealed with chemical-resistant paint.
- Floors of chemical storage buildings should have a continuous sill to contain spills and should not have a drain. A sump is acceptable.
- Shelving should be fabricated from plastic or reinforced metal. Metal shelving should be painted to avoid corrosion. Wood shelving should never be used because of its ability to absorb spilled pesticides.
- Automatic exhaust fans and an emergency wash area should be provided
- Locate fan and light switches outside the entrance to the building to facilitate ventilation of building before entrance of staff.
- Store chemicals in original containers. Never store them in containers that might be mistaken as packaging for food or drink.
- Arrange containers so the labels are clearly visible. Securely fasten loose labels to ensure containers and associated labels are kept together.
- Damaged labels should be replaced immediately.

- Store flammable chemicals separate from those that are non-flammable.
- Store liquid materials below dry materials to prevent any leaks from contaminating dry products.
- Ensure that oil containers and small fuel containers (service containers) are properly labeled and stored within the facility.
- Ensure that all containers are sealed, secured, and properly labeled. Use only regulatory agency-approved, licensed contractors for disposal.

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. In addition, storing and maintaining equipment properly will extend useful life and reduce repairs.

Best Management Practices

- Store and maintain equipment in a covered area complete with a sealed impervious surface. This limits risk of fluid leaks contaminating the environment and facilitates the early detection of small leaks that may require repair before causing significant damage to the turf or the environment.
- Seal floor drains unless they are connected to a holding tank or sanitary sewer with permission from the local wastewater treatment plant.
- Store pesticide and fertilizer application equipment in areas protected from rainfall. Rain can wash pesticide and fertilizer residues from the exterior of the equipment and possibly contaminate soil or water.
- Store solvents and degreasers in lockable metal cabinets away from ignition sources in a well-ventilated area. These products are generally toxic and highly flammable. Never store them with fertilizers or in areas where smoking is permitted.
- Never allow solvents to drain onto pavement or soil, or discharge into waterbodies, wetlands, storm drains, sewers, or septic systems, even in small amounts.
- Keep an inventory of solvents and SDS for those materials on-site but in a different location where they will be easily accessible in case of an emergency.
- Keep basins of solvent baths covered to reduce emissions of volatile organic compounds.
- When possible, replace solvent baths with recirculating aqueous washing units. Soap and water or other aqueous cleaners are often as effective as solvent-based products and present a lower risk to the environment.
- Always use appropriate PPE when working with solvents.
- Never allow solvents or degreasers to drain onto pavement or soil, or discharge into waterbodies, wetlands, storm drains, sewers, or septic systems.
- Collect used solvents and degreasers in containers clearly marked with contents and date. Schedule collection by a commercial service.
- Blow off all equipment with compressed air to reduce damage to hydraulic seals.

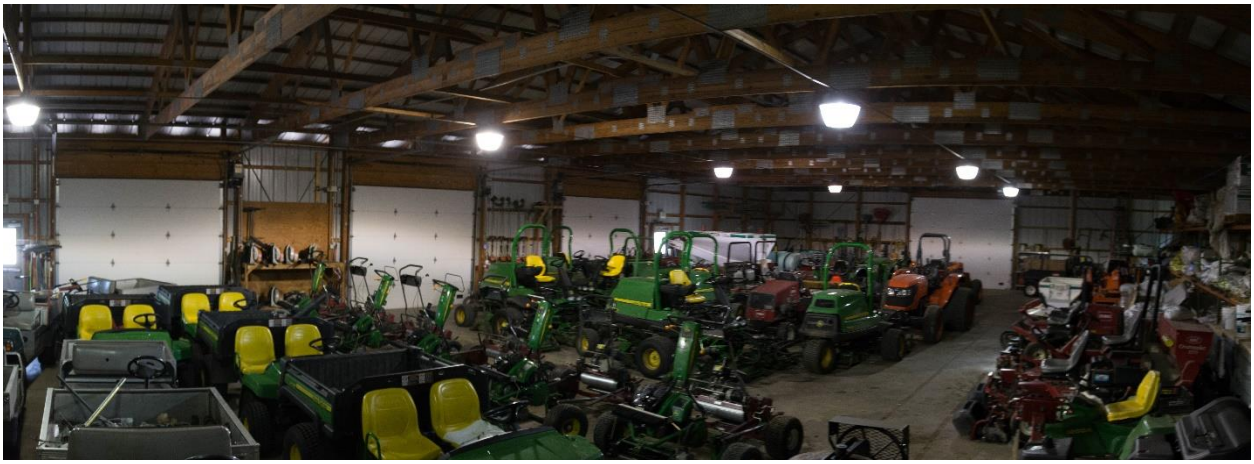


Figure 41. Equipment storage at Baltimore Country Club. Photo credit: Mark Jones.

Equipment Washing

Preventing runoff in equipment wash areas from directly or indirectly reaching surface waters, drain pipes, or storm sewers is an important BMP, as washwater can contain organic material, such as grass clipping and soil, as well as soaps, oil residue, fertilizer, and pesticide residue. In addition, minimizing the use of detergents and using only biodegradable non-phosphate detergents is a BMP.

For equipment other than any with potential pesticide residue, the primary concerns related to washwater are the nutrients (nitrogen and phosphorus) associated with the clippings. To reduce the amount of organic debris in washwater, grass clippings should be blown off equipment with compressed air instead of, or prior to, washing with water. In the wash area, a catch basin to collect remaining grass clippings should be installed and maintained. Clippings can be cleaned up and then composted or removed to a designated debris area. 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 or storm drains.

For equipment that may have pesticide residue, BMPs should be followed to ensure that washwater does not become a non-point source of pollution. 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 label.

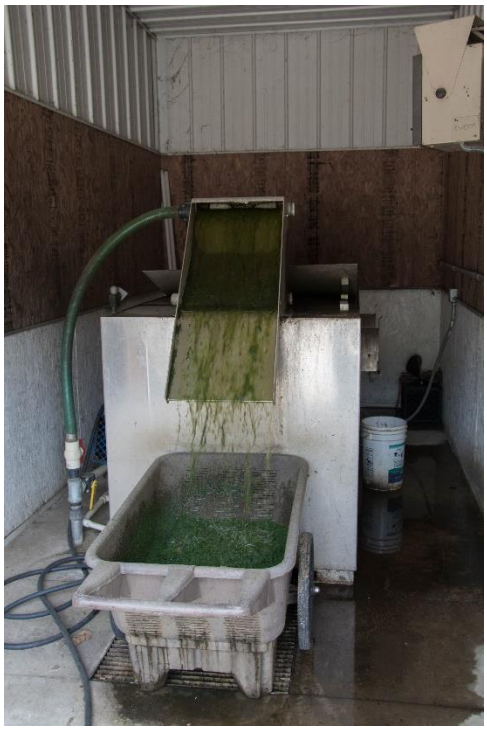


Figure 42. Clippings should be separated from washwater and managed properly to avoid water quality impacts from nitrogen and phosphorus. Photo credit: Mark Jones.

Best Management Practices

- Brush or blow off with compressed air grass-covered equipment before washing.
- Consider the use of a closed-loop washwater recycling system.
- Equipment washing areas should drain to an oil/water separator before draining to a sanitary sewer or holding tank.
- Avoid washing any equipment in the vicinity of wells or surface waterbodies.
- Wash equipment over a concrete or asphalt pad that allows the water to be collected. After the residue dries on the pad, collect, compost, or spread on turf.
- Minimize the amount of water used to clean equipment. This can be done by using spray nozzles that generate high-pressure streams of water at low volumes.
- Use spring-operated shut-off nozzles.
- Minimize the use of detergents and 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 cause the permitted storage volume of the stormwater system to be exceeded.
- Do not discharge washwater to surface water or groundwater either directly or indirectly through ditches, storm drains, or canals.
- Never discharge to a sanitary sewer system without written permission from the utility.
- Never discharge to a septic tank.
- Do not wash equipment used to apply pesticides on pads with oil/water separators.
- 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.

Figure 43. Equipment washing at Baltimore Country Club. Photo credit: Mark Jones.

Figure 44. Closed loop washwater recycling system at Baltimore Country Club. Photo credit: Mark Jones.

Fueling Facilities

Safe storage of fuel, including the use of above-ground tanks and containment facilities, is critical to the protection of the environment. In Maryland, all underground fuel storage tanks and 10,000 gallon or larger above-ground storage tanks are regulated by MDE. Local laws and regulations related to storage of fuel may vary.

Best Management Practices

- Locate fueling facilities under roofed areas with a concrete (not asphalt) pavement. Areas should be equipped with spill-containment and recovery facilities.
- Use of above-ground fuel tanks is preferred.

Waste Handling

All chemicals, chemical containers and packaging, and other wastes should be disposed of properly. 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. Pesticide specific waste handling requirements are discussed in the "Pesticide Management" chapter of this document.

Best Management Practices

- Collect used solvents and degreasers, place them into containers marked with the contents and the date, and then have them picked up by a service that properly recycles or disposes of them. Never mix used oil or other liquid material with the used solvents.

- Collect used oil, oil filters, and antifreeze in separate, marked containers and recycle them as directed by local and state authorities. The Maryland Environmental Service (MES) administers the Maryland Used Oil Recycling Program.
- Lead-acid batteries should be properly recycled. If not, they are classified as hazardous waste.
- Store old batteries on impervious surfaces where they are protected from rainfall and recycle them as soon as possible.
- Recycle used tires.
- Recycle or dispose of fluorescent tubes and other lights.

Unintended Releases

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. The following should already be in place in case of an unintended release: an emergency plan, spill kit, and first aid kit. Staff should be trained ahead of time in the proper procedures to ensure an effective response. Specific requirements for unintended releases of pesticides are covered in the "Pesticide Management" chapter of this document.

Best Management Practices

- Be prepared prior to any accidental release of chemicals.
- Clean up small spills as quickly as possible. For help cleaning up larger spills, contact CHEMTREC (800-424-9300).
- In the event of a spill, contact the MDE Emergency Response Division (866-633-4686) and the National Response Center (800-424-8802) to determine if the amount constitutes a reportable quantity.

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